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UNITED STATES GEOLOGICAL SURVEY

J. W. POWELL, DIRECTOR

THE

MESOZOIC ECHINODERMATA

OF THE

UNITED STATES

BY

WILLIAM BULLOCK CLARK

WASHINGTON
GOVERNMENT PRINTING OFFICE
1893

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LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF MESOZOIC INVERTEBRATES,
Washington, D. C., October 15, 1891.

SIR: I herewith transmit the manuscript of a memoir on the Mesozoic Echinodermata of the United States by Dr. William B. Clark, which you authorized him to prepare as a part of the work of the division of the Survey in my charge. I recommend that it be published as a bulletin of the Survey.

Very respectfully,

C. A. WHITE,
Geologist in charge.

Hon. J. W. POWELL,
Director U. S. Geological Survey.

PREFACE.

The present bulletin on the Mesozoic Echinodermata of the United States is the first of a series of reports on American fossil radiates. The material for a review of the Cenozoic Echinodermata has already been collected, and the results of that work will be shortly added.

The investigation of the Mesozoic Echinodermata, first undertaken at the request of Dr. C. A. White, was intended to include only the material in the possession of the U. S. National Museum, but the necessity for wider comparisons and a general treatment of American species became apparent as the work advanced. The larger collections in other institutions were accordingly drawn upon, and as a result the number of new forms has been greatly increased, while misconceptions that have hitherto existed as to the limitations of many of the earlier species have been rectified.

Much poor material that indicates other and new species has been ignored in this review, so that further collections will doubtless largely increase the number of American forms.

The writer is under great indebtedness to Prof. Robert T. Hill for information in regard to the geological range and localities of many of the Texan species and for the loan of a large amount of material. Further, the writer desires to extend his thanks to Prof. Angelo Heilprin, of the Academy of Natural Sciences of Philadelphia, Prof. R. P. Whitfield, of the American Museum of Natural History, New York, Prof. Alpheus Hyatt, of Boston, Prof. O. C. Marsh, of New Haven, Mr. G. Wolf Holstein, of Texas, Dr. G. Hambach, of St. Louis, Prof. Samuel Calvin, of the University of Iowa, Mr. E. T. Dumble, State Geologist of Texas, Mr. E. J. Pond, of Washington, Mr. F. A. Sampson, of Sedalia, Missouri, and others, for the opportunity to use the important collections in their possession.

The writer is under the greatest obligations to Mr. C. R. Keyes, who has executed the very complete and accurate series of structural drawings, and whose extensive knowledge of the Echinodermata gives to the other illustrations prepared by him an especial value for determinative purposes. The author is also indebted to Mr. H. C. Hunter for the care he has shown in the preparation of the drawings intrusted to him.

THE MESOZOIC ECHINODERMATA OF THE UNITED STATES.

By William Bullock Clark.

INTRODUCTION.

The need of a revision of American systematic paleontology is nowhere more apparent than in the subkingdom of the Echinodermata. The valuable contributions of Wachsmuth and Springer upon the Paleozoic Crinoidea have largely covered the field for that division, while as yet nothing exhaustive has been attempted for the Mesozoic and Cenozoic. The value of the Echinodermata in the later horizons may not be so great as in the earlier, yet many important forms of wide geological and geographical range are found in both the Mesozoic and Cenozoic.

The reports of Morton upon Atlantic Coast species and of Roemer and Shumard upon Texan types are among the most important publications upon North American Mesozoic Echinodermata, but the articles are in each case difficult of access to the student and the results recorded wholly inadequate for present systematic or stratigraphical requirements.

In previous discussions of North American Echinodermata no attention has been paid to the South American forms, so that much confusion exists as to the true relations of the two faunas. Very little is known of the geographical range of the various species, but that many of the North and South American forms described under different names are identical is beyond doubt. When more exhaustive collections have been made and comparisons instituted, this similarity of echinoderm faunas in the two continents will be made apparent. The present poor descriptions and meager figures afford a very inadequate basis for such a study.

The identity of American with European species seems doubtful, although a few forms present characters that closely ally them.

In the succeeding pages is presented a complete bibliography of works on North American Mesozoic Echinodermata, and of certain others that deal with closely related forms.

In the systematic review that follows, and that constitutes the major portion of the report, descriptions of moderate length are accorded the

different species. It has been deemed sufficient to present simply those characteristics that are necessary for an accurate determination of the forms, omitting many of the minute though interesting details of structure. A table is given showing the geological range of the different American Mesozoic species. In conclusion an index to the various terms employed by those who have written on the Mesozoic Echinodermata of the United States is presented.

An attempt has been made to very fully illustrate all the species. Many of the details of structure, not recorded in the descriptive portions of the report, are shown on the various figures.

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SYSTEMATIC REVIEW.

CRINOIDEA.

UINTACRINIDÆ.[1]

Calyx unsymmetrical, without column. Basis monocyclic. Basals five, inclosing a centro-dorsal plate. Radials 5×3. Interradials numerous, the lowest between the second radials. Arms 5×2, very long, with pinnules.

UINTACRINUS Grinnell.

UINTACRINUS SOCIALIS Grinnell.

Plate I, Figs. 1a–c; Plate II, Figs. 1a–e.

Uintacrinus socialis Grinnell, 1876. Amer. Jour. Sci., 3d ser., vol. 12, pp. 81–83, Pl. IV, Figs. 1–2b.

Uintacrinus socialis Meek, 1876. U. S. Geol. and Geog. Survey of the Territories, Bull. vol. 2, pp. 375–378, Figs. A–B.

Determinative characters.—Calyx subglobose, composed of numerous thin, slightly convex plates, joined together by channeled sutures and without distinct surface markings. Column wanting. Basis composed of a small pentagonal centro-dorsal plate, surrounded by a circle of five small similar basals. Encircling the pentagonal base and alternating with the basals are five large radials, hexagonal in outline and wider than high. Succeeding the primary radials are secondary and tertiary radials, the latter axillary in form. The primary radials alone are in contact, the others being separated by interradials. Succeeding the radials are several distichals, which gradually change to true rounded brachials, forming ten long arms. Between the distichals are two large interdistichals, situated one above the other. From the second distichal, which is axillary in form, a row of plates diverges interradially, alternating with similar plates from the same distichal of the adjacent area. From the fourth distichal a like row of plates diverges radially, alternating with similar plates from the same distichal of the other half of the same area. Higher up other rows diverge both radially

[1] The family of the Uintacrinidæ, as characterized by von Zittel in his "Handbuch der Paleontologie," includes only two species, *Uintacrinus socialis* Grinnell, from the Cretaceous of Utah and Kansas, and *U. westfalicus* Schlüter from the Cretaceous of Westfalia. The genera Uintacrinus and Marsupites alone among Mesozoic types afford points for comparison with the Paleozoic crinoids. Neumayr in "Die Stämme des Thierreiches" considers the difficulty of bringing them into a consistent classification with the other crinoids but suggests several points of relationship between Uintacrinus and the Ichthyocrinidæ.

and interradially until true pinnules are developed on the free brachials. The brachials are united either by articulation or sizygial suture, in the latter case the line of union often becoming obliterated. The interradial plates, eight or nine in number, form a rounded, slightly elevated shield-like area, surrounded above by the alternating rows of plates that diverge from the second distichal.

Dimensions.—Calyx: height, 2 inches; breadth, 2¼ inches. Arms: length, 20 inches (?).

Description.—The first specimen of this species was collected by Prof. O. C. Marsh in 1870 from the Cretaceous of the Uinta Mountains of Utah and by him compared with Marsupites of the English chalk.[1] Subsequently other specimens were obtained from Kansas, and in 1876 were described by Mr. G. B. Grinnell, an assistant to Prof. Marsh at that time, under the name of *Uintacrinus socialis*. Prof. F. B. Meek, who had already in his possession similar material, added, in the Bulletin of the U. S. Geological and Geographical Survey of the Terrtories, descriptions of certain points in the structure not mentioned by Grinnell.

All the specimens hitherto collected are much compressed, so that the original form is with difficulty determined. In general, on any single specimen only the plates of one side are preserved sufficiently well for identification.

The calyx is subglobose, with ten long, simple arms extending from the upper side (Pl. I, Fig. 1*b*). The plates are thin, slightly convex, and joined together by simple, though well marked, sutures, that are generally slightly channeled. The calyx is without column or stalk, and belongs to the class of "free" forms.

The basis is composed of a centro-dorsal plate, surrounded by five basals. The centro-dorsal plate is doubtfully visible upon only a single specimen. Judging from the problematical portion of the plate exposed, and the shape of the lower edges of the basals, it must be small and pentagonal in form. Its presence was not noted by either Grinnell or Meek, upon the specimens examined by them. The five basals, also undescribed by previous writers, encircle the centro-dorsal plate (Pl. II, Figs. 1*a*, 1*b*). They rest with one side against the latter and terminate in a sharp angle above. The whole basis forms a nearly perfect pentagon, which is slightly depressed where the line of juncture of two adjacent basals reaches the edge. Five large primary radials surround the basals and alternate with them. They are six or seven sided, the latter occurring when the edge toward the basis is broken by an angle into two portions. These plates are wider than high, and come in contact with one another only in the lower portion of each side. The upper parts are separated by the interradial area, as are the secondary and tertiary radials that succeed the primary. The secondary radials are smaller than the primary, and are separated by horizontal suture lines from them. The tertiary radials are axil-

[1] Amer. Jour. Sci., 3d ser., vol. 1, 1871, p. 195.

lary, bearing two large distichals that come in contact only along a portion of their lateral margins (Pl. 1, Fig. 1*c*). Succeeding the primary distichals are four others of large size and varying shape, beyond which the plates rapidly decrease in size and change to true brachials (Pl. 1, Fig. 1*c*).

In the angle between the larger distichals of each radial series are two large interdistichal plates. The lower of these comes in contact with the primary distichals in the angle formed by the upper portions of the lateral margins of those plates. It likewise touches the sides of the second and a portion of the third distichal. The upper interdistichal rests with horizontal edge upon the lower, and is embraced between the upper portion of the third distichals and the lower portion of the fourth, ending above with angular margin between the modified plates that branch from the fourth distichals, to be presently referred to.

The second distichals are axillary and support interradially rows of plates, the first of each row separated from one another by the interradials (Pl. 1, Fig. 1*a*). The first plates are smaller than the second of the same row, which meet with a vertical suture and slightly overlap, a character which becomes more pronounced higher in the series, so that true alternation results. Beyond the third plate a rapid reduction in size of plates takes place. Ten to twelve plates have been recognized in each row.

From the fourth distichals, which are likewise axillary, similar rows diverge radially (Pl. 1, Fig. 1*c*). From the fifth distichals are other rows interradial in position, while the seventh again bear radial branches. These rows gradually grow smaller and as the brachials become movable appear as pinnules. The lower rows become incorporated in the calyx, and as they are immovable have become modified for the position they occupy.

The interradials are eight, nine, or more in number and form an elevated, shield-like area, each plate likewise showing a slightly convex surface (Pl. 1, Fig. 1*a*). The arrangement of the plates does not vary; seven in an oval band inclose the eighth, or eighth and ninth, according to the number of interradials. The lower interradial occupies the angle between the upper portions of the lateral margins of the primary radials and likewise separates the secondary radials. The two upper interradials occupy the angle formed by the branches from the second distichals and the distichals themselves. The four other interradials of the outer band lie two on each side between the lower interradial and the upper pair of plates. The lower two of these four are in contact, while the upper two are separated by the inner plate or plates. In contact with the four plates are the secondary and tertiary radials and the first and second distichals. The inner plate is more frequently replaced by two smaller ones irregular in outline and position.

The brachial plates are the continuation of the distichals and form ten simple arms. They gradually assume a half-round, horseshoe-

shaped outline, the depression on the inner surface increasing until a well-marked ambulacral furrow is produced. The plates are likewise perforated a short distance in front of the same. The plates are united in two ways, by articulation (Pl. II, Fig. 1*c*) and by sizygial suture (Pl. II, Fig. 1*d*), the former producing a movable joint, the latter uniting adjacent plates immovably. Rows of pinnules are developed on the inner surface of the arms alternately from opposite sides, each row branching from the epizygale, where the sizygial suture is observed (Pl. II, Fig. 1*c*).

The arms attain very great length. Grinnell mentions a specimen examined by him where the arms measured 8 inches, and one examined by the writer was very nearly as long. Grinnell thinks the arms may reach 2 feet in length.

Related forms.—The present species is closely allied to *Uintacrinus westfalicus*, described by Schlüter[1] in 1878 from the Upper Cretaceous (Senonian) of Recklinghausen, in Westphalia. It is the only other species of this genus thus far described, so that a statement of the affinities of the two forms is important. In the composition of the basis the two species are very nearly identical. The radials and distichals show very slight differences, but the brachials in *U. socialis* are decidedly broader than in *U. westfalicus*. In the number and arrangement of the interradials the most marked difference is manifested. In *U. socialis* seven interradial plates encircle the eighth, or eighth and ninth, as the case may be, while in *U. westfalicus* the interradials are five in number, all of which come in contact with plates of other areas. Several minor differences appear in the rows of small plates that branch from the distichals. Otherwise, however, there is a marked similarity in the arrangement and form of the several plates. In general outline the two species are very similar.

Locality and geological horizon.—The first specimen was found on the slopes of the Uinta Mountains, in Utah, by Prof. Marsh, associated with *Ostrea congesta* Con., a typical Cretaceous form. Later, others were found in Kansas, associated with Odontornithes, Pterodactyls, and mosasauroid reptiles, likewise characteristic of the Cretaceous. Meek assigns the species to the Niobrara Group, a horizon of the upper Cretaceous.

Collections.—Peabody Museum, New Haven; U. S. National Museum.

APIOCRINIDÆ.

Calyx regular, composed of thick, articulated plates; basals five; radials 5 × 1–3. Exceptions frequent. Arms strong, numerously divided. Column long.

[1] Zeitschr. der Deutsch. geol. Gesells., XXX, 1877, pp. 55–63, Pl. IV.

BOURGUETICRINUS D'Orbigny.

BOURGUETICRINUS ALABAMENSIS de Loriol.

Plate III, Figs. 1*a–c*.

Bourgueticrinus alabamensis de Loriol, 1882. Cincinnati Soc. Nat. Hist. Jour., vol. v, p. 118, Pl. v, Fig. 1, 1*a*, 1*b*.

As it has been impossible for the writer to obtain possession of the type of this species the description of de Loriol, as translated by Prof. S. A. Miller, is given verbatim: "This species is as yet known only by the basal cone which supports the calyx, and which is composed of several enlarging segments of the column surmounted by the basal plates. The height of the inverted cone is 5^{mm}; the diameter of the basal plate is $3\frac{1}{2}^{mm}$, and that of the inferior segment of the column is 3^{mm} in its major axis. Its form is faintly swollen in the middle; the surface is smooth. The sutures are very indistinct, and it is a difficult matter to determine what was the height of the basal plate. The superior face of the cone carries five slender and comparatively elevated radiating ridges, which bound five deep depressions in which the basal pieces of the calyx were lodged; in the center an enlargement of the central canal constitutes the bottom of the calyx cavity. The articular face of the lower joint of the column forming the inferior end of the cone is elliptical, but the length of its major axis does not, however, much exceed that of its minor axis. It is slightly concave and encircled by a feeble rim along the circumference line; the transverse articular ridge process is reduced to two elongated tubercles which proceed from the marginal rim. Central canal comparatively large."

Related forms.—"Although this species is still very imperfectly known one can affirm that it is certainly distinct from *Bourgueticrinus ellipticus* Miller, by the much less swollen form of the basal cone, which is but slightly convex in outline, and by the facts that the lower segment of the cone is already elliptical and already possesses the rudiments of a transverse articular ridge. Furthermore, the radiating carinæ are very much more salient, and consequently the depressions which they separate very much deeper. Finally, by its central canal being relatively much larger."

Locality and geological horizon.—" Livingstone, Alabama, Ripley Group of the Cretaceous, or at the top of the Rotten limestone."

Collection.—Cincinnati Society of Natural History.

PENTACRINIDÆ.

Calyx small, "composed of five basals and five radials with underbasals in one genus. The rays divide from one to eight times. The stems bear verticils of cirri at intervals. Two joints are united by syzygy at each node, to the upper one of which the cirri are articulated.

The internodes are traversed by five ligamentous bundles, which are interradially disposed, and give rise to a more or less petaloid figure on the joint-faces. No root nor radicular cirri." (P. H. Carpenter.)

PENTACRINUS Miller.

PENTACRINUS ASTERISCUS Meek and Hayden.

Plate III, Figs. 2 *a–d*.

Pentacrinus asteriscus Meek and Hayden, 1858. Philadelphia Acad. Nat. Sci. Proc., vol. 10, p. 49.

Pentacrinus asteriscus Meek and Hayden, 1860. Philadelphia Acad. Nat. Sci. Proc., vol. 12, p. 419.

Pentacrinus asteriscus Meek, 1864. Smith. Misc. Coll. (177), p. 27.

Pentacrinites asteriscus Meek and Hayden, 1865. Pal. Upper Missouri, Smith. Contr. Knowledge (172), p. 67, Pl. III, Fig. 2.

? *Pentacrinites asteriscus* Whitfield, 1880. Geol. Black Hills of Dakota, p. 345, Pl. III, Figs. 1, 2.

Determinative characters.—Calyx branching. Stem or column composed of small, pentagonal joints, rather thick, that bear at intervals small rounded processes or cirri. The column joints are connected by crenated ridges arranged in pentapetalous form. The stem is perforated by a central canal.

Dimensions.—Column: breadth of joint, $\frac{1}{20}$ to $\frac{1}{7}$ inch; length of joint, $\frac{1}{30}$ inch.

Description.—This species was first described by Meek and Hayden in 1858, in the Proceedings of the Academy of Natural Sciences of Philadelphia, from several fragments of the column. The calyx or arms are not known, and, as in the succeeding species, the distinguishing characteristics are confined entirely to the column joints. On the large slab figured by Meek and Hayden in the Paleontology of the Upper Missouri are several detached portions of the column 1 to 2 inches in length. The sutures are clearly marked and the nodal can be readily separated from the internodal joints. Of the latter, ten are plainly seen between two nodes on one fragment (Pl. III, Fig. 2 *a*), while in other instances the number seems to be slightly greater. All the joints are rather thick (Pl. III, Fig. 2 *c*). Five cirrus scars are found on each node in the reentering angles. Each node is joined to the underlying internode by syzygial suture, while the overlying plate is connected by crenulated ridges, as are also the internodal plates themselves. The arrangement of these ridges is distinctly petaloid (Pl. III, Fig. 2 *b*). The reentering angles of the outer surface of the stem are not deep, so that the points of each star-shaped prolongation are short and broad.

The cirri are composed of small round joints that are longer than broad. They are joined, as far as could be discerned, by simple sutures (Pl. III, Fig. 2*d*).

There is some doubt whether the form referred by Whitfield to *P. asteriscus* in the Geology of the Black Hills, and so figured and de-

scribed, should be considered such. The reentering angles are much too deep. Unfortunately there is no side view of the plates.

Related forms.—This species is wholly unlike the other American forms. In the first place, it is much smaller than *P. Whitei*, and *P. Bryani* and has a distinctly different form from *P. Whitei* with which it has been hitherto confounded. In *P. Whitei* the reentering angle is made deeper and of different shape. Likewise the crenulations of the petaloid area of the joints are differently arranged. The joints themselves are also relatively much thicker.

Locality and geological horizon.—Reported by Meek and Hayden[1] "associated with other Jurassic fossils from the southwest base of Black Hills, and opposite Red Buttes, North Platte river," the former in Dakota, the latter in Nebraska. In the Check List of Invertebrate Fossils from the Jurassic, Meek also mentions Idaho and Colorado. Peale mentions the occurrence of specimens in Idaho.

Collection.—U. S. National Museum.

Pentacrinus Whitei Clark.

Plate III, Figs. 4*a–c*.

Pentacrinites asteriscus White, 1875. U. S. Geog. Surys. west of 100th Meridian, vol. 4, 1875, p. 162, Pl. XIII, Figs. 6*a-b*.

?*Pentacrinites asteriscus* (?) Hall and Whitfield, 1877. U. S. Geol. Expl. 40th Parallel, vol. 4, pp. 280, 281, Pl. VI, Fig. 16.

?*Pentacrinites asteriscus* Whitfield, 1880. Geology of Black Hills of Dakota, p. 345, Pl. III, Figs. 1, 2.

Determinative characters.—Calyx wanting. Column composed of large, thin, pentagonal joints that possess deep reentering angles. The crenulated ridges of the suture have a petaloid arrangement. Column perforated by central canal.

Dimensions.—Column: breadth of joint, $\frac{1}{4}$ to $\frac{1}{3}$ inch; length of joint, $\frac{1}{30}$ inch.

Description.—In the volume upon paleontology of the quarto publications of the U. S. Geological Surveys West of the One-Hundredth Meridian, Dr. White figures and refers a form to *Pentacrinites asteriscus* Meek and Hayden, that belongs evidently to another species. A comparison by the writer of the specimens figured by Meek and Hayden and by White shows that the differences are too great to permit their reference to the same species. The name *P. Whitei* is therefore suggested for the new form in honor of the distinguished scientist who has done so much to advance our knowledge of American Mesozoic geology and paleontology. As with *P. asteriscus* only portions of the column of *P. Whitei* have been discovered. The outer side of the column is furrowed by deep reentering angles producing five prominent ridges at the salient angles. The joints are relatively thin, with rounded edges, so that the column does not appear compactly

[1] Paleontology Upper Missouri, p. 67.

formed from outward aspect (Pl. III, Fig. 4c). A distinctly petaloid arrangement of the crenulated ridges is exhibited (Pl. III, Figs. 4a, 4b).

Hall and Whitfield refer to *Pentacrinites asteriscus* Meek and Hayden certain specimens collected by Hague in Nevada from "limestone of supposed Triassic age." There is some doubt as to the identity of this form, though the description and figures render it probable that it should be referred to *P. Whitei.*

The form figured and described by Whitfield from the Black Hills under the name *P. asteriscus* is, on account of the deep reentering angles, to be probably associated with *P. Whitei.* No side view of the joints is given by which comparison may be made.

Related forms.—Separated from *P. asteriscus*, with which it has been hitherto confounded, by its larger size, deeper reentering angles, and relatively much thinner plates.

Locality and geological horizon.—The type specimens of this form are from the Jurassic of Salt creek and Diamond valley, Utah.

Collection.—U. S. National Museum.

Pentacrinus Bryani Gabb.

Plate III, Figs. 3a–b.

Pentacrinus Bryani Gabb, 1876. Philadelphia Acad. Nat. Sci. Proc., vol. 28, p. 178, Pl. 5, Figs. 1, 1a, 1b.

Determinative characters.—Calyx wanting. Column composed of moderately large, rather thick, pentagonal joints, with sharp reentering angles. The crenulated ridges are broadly petaloid and each area is rounded at its outer extremity. Column perforated by canal.

Dimensions.—Column: breadth of joint, $\frac{1}{20}$ inch; length of joint, $\frac{1}{4}$ inch.

Description.—Two small fragments of the stem of this form are described by Gabb in the Proceedings of the Academy of Natural Sciences of Philadelphia for 1876. As the only representative of this family reported from the American Cretaceous it possesses considerable interest. The column is composed of moderately large, thick joints, that in breadth reach quite one-quarter of an inch in diameter and about one-fifth of that in thickness. The broad rounded ridges at the salient angles of the pentagonal outline form a nearly unbroken line, while the furrow at the reentering angles is alternately depressed and elevated in successive joints. The edge of each joint is slightly rounded. The crenulated surfaces form five broad petaloid areas distinctly rounded at the outer extremities (Pl. III, Fig. 3a) and unite near the inner edge of the reentering angles to form a double flat-topped ridge that reaches to the central canal, around which there is likewise a slight elevation. The crenulations are visible on the outer surface of the column. The column is perforated by a central canal.

Related forms.—As the only representative of this family in the

Cretaceous, there is little among the American forms with which it may be compared, especially as the two Jurassic types previously described show marked differences in every particular.

Locality and geological horizon.—The specimens described by Gabb and examined by the writer are from the yellow limestone of Vincentown, New Jersey. The yellow limestone belongs to the middle marl bed and is upper Cretaceous.

Collections. Philadelphia Academy of Natural Sciences; Johns Hopkins University.

ASTEROIDEA.

OPHIURIDÆ.

Body star-shaped, with central disk and elongated arms, which are distinctly separated from the disk. The ambulacral grooves are generally covered with plates.

OPHIOGLYPHA Lyman.

Ophioglypha bridgerensis (Meek).

Plate IV, Figs. 2*a–b*.

Ophioderma ? bridgerensis Meek, 1873. U. S. Geol. Surv. Territories for 1872, p. 475.
Ophioderma ? bridgerensis White, 1883. U. S. Geol. and Geog. Surv. of the Territories for 1878, pp. 8, 9, Pl. 12, Fig. 12*a*.

Determinative characters.—Disk composed of numerous small imbricating plates. Upper arm plates wider than long, the outer angles sharp and extending between the side arm plates, which are slightly smaller. Under arm plates long and nearly rectangular in shape.

Dimensions.—Diameter of disk, $\frac{1}{4}$ inch. Length of arm, $\frac{3}{4}$ inch. Width of arm near disk, $\frac{1}{20}$ inch.

Description.—The single specimen of this species thus far found is described in a foot-note to a list of specimens appended to the paleontological report of F. B. Meek in the Annual Report of the U. S. Geological Survey of the Territories for 1872, and redescribed and figured by Dr. C. A. White in the Annual Report for 1878 of the same organization. This specimen, which has been carefully examined by the writer, presents the upper surface of the disk and fragments of the five arms. Upon all but one fragment the upper and side arm plates are shown, while upon that a minute portion of the under surface of a single arm with the under arm plates and ambulacral openings is preserved.

The disk is described by Meek as "depressed, nearly circular, showing on the dorsal side ten ovate-subtrigonal radial plates, that are joined together over the inner ends of the arms, so as to form five pairs." A close examination of the specimen shows that the disk is made up of numerous small imbricating plates, and that the supposed division into

ten, as mentioned by Meek, may be explained by the fractured condition of the poorly-preserved specimen.

The arms are small, and are, as stated by Meek, perhaps $\frac{3}{4}$ inch in length, although none of them are preserved entire. The upper arm plates are wider than long, and hexagonal in form (Pl. IV, Fig. 2*b*). The outer angles are sharp, and are embraced between the upper portions of the side plates. The latter are slightly swollen, but are not shown in their entire length. The lower arm plates are poorly preserved, but so far as exhibited are long and narrow, nearly rectangular in shape and slightly swollen in their central portions.

Related forms.—There is some doubt as to the generic position of this species. So many of the distinctive characters are wanting that a definite determination in that particular is quite impossible, but from the apparent structure of the disk, formed of numerous imbricating plates, its reference to *Ophioglypha* seems probable. The only other form, *O. texana*, has a somewhat smaller and differently constructed disk so far as can be discerned, and both the upper and under arm plates are of different shape.

Locality and geological horizon.—This form is reported by Meek, from the "last foot of Bridger Peak, 4 miles north of Fort Ellis, Montana," associated with undeterminable species of the genera *Gryphæa*, *Avicula*, *Inoceramus*, *Crassatella*, *Pholadomya*, *Turritella* and *Gyrodes*, that denote the Cretaceous age of the strata.

Collection.—U. S. National Museum.

Ophioglypha texana Clark.

Plate IV, Figs. 1*a–c*.

Determinative characters.—Disk round; composition indistinct. Arms long, with wedge-shaped under arm plates about as wide as long; upper arm plates about twice as wide as long.

Dimensions.—Diameter of disk, $\frac{1}{5}$ inch; length of arm, 2 inches; width of arm at disk, $\frac{1}{12}$ inch.

Description.—The determination of this species is dependent upon three fairly well preserved forms that are grouped upon a single slab of limestone, all with the lower side exposed. The surface upon which they rest is considerably weathered, so that many of the details of structure have consequently suffered. The general form of the disk is preserved, though its composition can not be made out. In many instances the arm plates have disappeared, leaving only the skeletal pieces. Where preserved, the under arm plates are wedge-shaped and about as wide as long (Pl. IV, Fig. 1*c*). The upper arm plates, which are shown only as impressions upon the limestone, are nearly twice as wide as long, and have their lateral edges rounded (Pl. IV, Fig. 1*b*).

Related forms.—Although this form can not with certainty be referred to *Ophioglypha*, it possesses, however, many points of similarity to

the previous species, from which, on the other hand, it is separated by the different shape of the disk and of the under and upper arm plates.

Locality and geological horizon.—The slab containing the specimens described is from the Denison beds of the Washita division of the Comanche series (Lower Cretaceous), 6 miles north of Fort Worth, on the banks of Fossil creek. It is found associated with *Ostrea quadriplicata* Shumard, *Stearnsia Robbinsi* White, and *Leiocidaris hemigranosus* (Shumard).

Collection.—U. S. National Museum.

STELLERIDÆ.

Body star-shaped or pentagonal, composed of a central disk and five prolongations of the same, called arms, that are portions of the body proper. Integument strengthened by calcareous plates irregularly arranged. Ambulacral furrow uncovered.

ASTERIAS Linnæus.

ASTERIAS? DUBIUM Whitfield.

Plate v, Fig. 2.

Asterias? dubium Whitfield, 1877. Prelim. Rept. Pal. Black Hills, p. 15.
Asterias? dubium Whitfield, 1880. Geol. Black Hills of Dakota, pp. 344, 345, Pl. 3, Fig. 3.

Determinative characters.—Imperfectly preserved forms of small size, with slender flexuous arms, apparently covered superiorly with longitudinal rows of plates.

Dimensions.—Length of arms, ¾ inch to 1¼ inches.

Description.—This interesting but doubtful form is thus characterized by Whitfield: "The specimens are not in condition to afford a full description of their specific characters. They are of small size, the rays being from three-fourths of an inch to one and one-fourth inches long, measuring from the center of the body. The rays are slender and flexuous, most of them being more or less curved in their direction and elevated along the middle, as shown on a gutta-percha cast taken in a natural mold of a group of three individuals. The upper surface is subangular, and in structure they are apparently composed of small uniform plates, placed in longitudinal rows. The center of the body or disk is marked by an obscurely pentangular depression on the upper surface. None of the specimens show the under side of the body or rays, so that the characters of these parts are entirely unknown.

"The species appears to have been somewhat abundant, judging from the condition in which they are grouped on the sandstone, and, although the specimens are obscure and too imperfect for positive determination and description, it has been thought best to designate them by names, as they will undoubtedly prove a characteristic form over a certain re-

gion and of a limited horizon. The sandstone is marked by the layers in which they are found by ripple or wave marks, having a width of about 3 inches, and indicates a near proximity to a shore line over the area where they were obtained, and that the individuals are probably stranded specimens. A single very imperfect impression of a lamellibranchiate shell is present on the same fragments of rock, but too imperfect for determination."

Related forms.—This very doubtful species scarcely admits of comparison with other forms. There is nothing hitherto reported from American strata that can be closely associated with it.

Locality and geological horizon.—This form is reported by Whitfield as occurring "in red sandstones of Jurassic age, 70 feet above the red beds, on the east side of Spearfish creek, near its junction with the Redwater, Black Hills, Dakota."

Collection.—U. S. National Museum.

GONIASTER Agassiz.

GONIASTER MAMMILLATA Gabb.

Plate v, Figs. 1*a–h*.

Goniaster mammillata Gabb, 1876. Philadelphia Acad. Nat. Sci. Proc., vol. 28, pp. 178, 179, Figs. 2, 2*a*, 2*b*.

Determinative characters.—Body pentagonal, provided with a dorsal and a ventral row of marginal plates that are narrower than high, and distinctly tumid on their outer surfaces. Only detached marginal plates preserved.

Description.—Gabb mentions the discovery of about thirty detached marginal plates of this species. They differ widely in shape by reason of their position upon the margin, but among those examined the majority are higher than wide, and swollen on the outer surfaces. Certain of the plates show marked protuberances upon the general level of the plate (Pl. v, Figs. 1*a*, 1*b*). The surface of the plates is punctate, the small depressions being arranged in rows that cross one another at right angles (Pl. v, Fig. 1*h*).

Related forms.—There are no American forms similar to this species with which it may be confounded, while the absence of all knowledge of the characters outside of a few marginal plates renders wide comparisons impossible.

Locality and geological horizon.—Yellow limestone of the middle marl bed of the Cretaceous from Vincentown, New Jersey.

Collections.—Philadelphia Academy of Natural Sciences; Johns Hopkins University.

ECHINOIDEA.

EUECHINOIDEA.

REGULARES.

CIDARIDÆ.

Test spheroidal. Ambulacral areas narrow, more or less flexuous, and covered only with very small tubercles. Interambulacral areas very wide, with two rows of large tubercles that bear the primary spines. The apical disk is composed of five genital and five ocular plates.

CIDARIS Klein emend. Lamarck.

CIDARIS SPLENDENS Morton.

Plate VI, Figs. 3*a–g*.

Cidaris (?) *sp.* Morton, 1829. Philadelphia Acad. Nat. Sci. Jour., 1st ser., vol. 6, p. 123.
Echinus sp. Morton, 1830. Amer. Jour. Sci., 1st ser., vol. 17, p. 287; vol. 18, Pl. III, Figs. 12, 13.
Cidarites splendens[1] Morton, 1841. Philadelphia Acad. Nat. Sci. Proc., vol. 1, p. 132.
Cidarites armiger Morton, 1842. Philadelphia Acad. Nat. Sci. Jour., 1st ser., vol. 8, p. 215, Pl. II, Fig. 1.
Cidaris armiger Gabb, 1859. Cat. Invert. Fossils, Cretaceous Formation, p. 18.
Cidaris splendens Gabb, 1859. Cat. Invert. Fossils, Cretaceous Formation, p. 18.
Cidaris armiger Clark, 1891. Johns Hopkins University Circulars, No. 87, p. 75.

Determinative characters.—Test of moderate size, spheroidal. Ambulacral areas narrow, flexuous, with four rows of granules between the pore pairs, the outer rows larger than the inner; imperfectly defined granules also appear between the pores of each pair. Interambulacral areas very wide, with seven or eight plates in each column, each plate bearing a tubercle of large size, that is characterized by a wide circular areola, smooth boss, and small perforated mamelon. Miliary area small and covered with numerous thickly-set granules of small size. Sutures sharply defined, depressed. Spines elongated, cylindrical, with longitudinal rows of sharp denticulated processes.

Dimensions.—Height, $\frac{7}{8}$ inch; width, $1\frac{3}{8}$ inches.

Description.—The first mention of this form is made by Morton in 1829, when he doubtfully referred a few fragments to *Cidaris* without an attempt at specific determination. Several of the more important characters were then given, but as the material examined included only detached plates and a few spines the description necessarily lacked much of completeness. In 1841 Morton proposed the name *Cidarites splendens* and then more accurately defined the species. In 1842 he redescribed and now for the first time figured the same form as *Cidar-*

[1] Morton doubtless intended to use the term *splendens* instead of *splendeus*, which is probably a typographical error. In the publication of 1842, where *armiger* is substituted, the form *splendens* is used.

ites armiger, a name which he stated he desired substituted for *C. splendens*. Gabb, in his Catalogue of the Invertebrate Fossils of the Cretaceous Formation of the United States, employs both names, mistaking them for independent species, although *C. splendens* is referred to as *C. splendeus*. The specimens examined by the writer are chiefly detached plates, and in no instance is the entire test preserved, as in the figure given by Morton. Two entire, or nearly entire, interambulacral areas, with part or all of the adjoining ambulacra, are among this material (Pl. VI, Fig. 3*a*). In these specimens the oral side is slightly more depressed than the aboral, although not to the extent exhibited in Morton's figure. The ambulacral areas, which are narrow and flexuous, have, between the poriferous avenues, four granules. In the center of each column of plates these granules are approximately of equal size, the outer rows slightly larger, but toward the disk or toward the mouth opening the inner rows rapidly diminish in size and finally disappear. The pores are oval in shape, with funnel-like openings exteriorly. Each row of pores is separated from that which accompanies it in the same avenue by a row of imperfectly defined granules that form an undulating ridge (Pl. VI, Fig. 3*c*).

The interambulacral areas are very wide and bear large tubercles, each of which covers the greater portion of its respective plate (Pl. VI, Fig. 3*b*). Upon the larger plates, in the center of each column, the areolas are circular, but become somewhat oval toward both disk and mouth opening. The outer edge of each areola is surrounded by a circle of large granules that give it a crenulated appearance. The areola rises from its depressed margin, gradually at first, then rapidly, to the boss, which reaches a marked elevation above the general level of the plate. The boss is of moderate width and smooth. From its center rises the mamelon, which is small, perforated, and slightly flattened upon the upper surface (Pl. VI, Fig. 3*d*). The miliary space is covered by small granules, that are most numerously developed along the median line of the interambulacra.

None of the specimens afford the apical disk. Strong auriculæ show the presence of powerful jaws.

The spines are slender, elongated, cylindrical, with longitudinal, serrated ribs that gradually become obsolete toward the base (Pl. VI, Fig. 3*e*). The collar is short and finely striated longitudinally (Pl. VI, Fig. 3*f*). The acetabulum is bordered by a smooth margin and is perforated in the center (Pl. VI, Fig. 3*g*).

Related forms.—In many particulars *Cidaris splendens* (Morton) shows points of comparison with *C. serrata* Desor of the European Cretaceous, but the American species differs from it in its smaller miliary areas and higher areolas, and also in the presence of only four rows of granules between the poriferous avenues.

Locality and geological horizon.—This species is reported by Morton from Timber creek, New Jersey, which establishes the horizon as that

of the yellow limestone of the middle marl bed (upper Cretaceous). It has also been found by the writer near Vincentown in the same formation.

Collections.—Philadelphia Academy of Natural Sciences; Johns Hopkins University.

CIDARIS TAYLORENSIS Clark.

Plate VI, Figs. 2*a–b*.

Determinative characters.—Test small. Interambulacral areas wide. Tubercles large, with circular areolas, much depressed marginally; boss crenulated; mamelon perforated. Miliary space narrow. Spines long, cylindrical, covered with small granules arranged in longitudinal rows.

Dimensions.—Test undetermined. Spines: length 1½ inches (?); width in broadest portion, $\frac{3}{16}$ inch.

Description.—The fragments of this form, although they admit of determination of but few of the important characters, warrant specific description from the fact that they are totally distinct from the only other representative of Cidaris from the Jurassic rocks of America. The small fragments of the interambulacral area and the spine occur together and doubtless formed part of the same individual. The interambulacral plates, of which only portions are preserved on the specimen figured, indicate a form of no great size (Pl. VI, Fig. 2*a*). The tubercles are large, with depressed areolas surrounded by a circle of large granules. The boss is crenulated and the mamelon perforated. The miliary space is apparently narrow, the tubercles of adjacent plates in the same column being nearly confluent.

The spine is long, gently tapering toward the base in the portion preserved, and covered with longitudinal rows of small granules (Pl. VI, Fig. 2*b*).

Related forms.—As the Jurassic strata of North America afford few fossil Echinodermata as compared with the Cretaceous, there are not many American types with which the present form may be compared. *Cidaris californica* Wilde, the only other representative of this genus thus far reported, has no portion of the test preserved, so that the comparison is limited to the spines. In *C. taylorensis* the spines are long and cylindrical, while in *C. californicus* they are short and thick set, and there is a totally different surface decoration.

Locality and geological horizon.—This species is known only from the Jurassic strata of Taylorsville, California.

Collection.—U. S. National Museum.

CIDARIS CALIFORNICUS Clark.

Plate VI, Figs. 1*a–b*.

Determinative characters.—Test unknown. Spines large, club-shaped, with rows of large granules that coalesce to form longitudinal ridges which extend from neck to point of spine.

Dimensions.—Spine: length, $\frac{7}{8}$ inch; breadth in thickest part, $\frac{3}{16}$ inch.

Description.—This species is based upon detached spines, four or five specimens of which are afforded in material from Taylorsville, California. They are distinctive in every way, and can not be mistaken, even in fragments. The specimens examined occur as casts, but so well preserved that impressions in gutta-percha, from which the drawings were made, show the characters completely. Each spine has a short narrow neck, beyond which it rapidly increases in size so as to give a club-shaped outline to the middle and upper portions. Rows of longitudinal granules cover the surface from the neck to the point of the spine, presenting the appearance of long serrated ridges (Pl. VI, Figs. 1*a–b*).

Related forms.—Separated from *C. taylorensis* by its club-shaped form and surface characters.

Locality and geological horizon.—This species is found in Jurassic strata at Taylorsville, California.

Collection.—U. S. National Museum.

CIDARIS TEXANUS Clark.

Plate VII, Figs. 1*a–c*.

Cidaris texanus Clark, 1891. Johns Hopkins University Circulars, No. 87, p. 75.

Determinative characters.—Test large, inflated. Ambulacral areas narrow, sinuous, with four rows of granules between the poriferous avenues, which at the ambitus are increased to six and toward the apical disk and mouth opening are reduced to two rows. Pores oval, separated by transverse elevations, which partially envelop the openings. Interambulacral areas wide, with large circular tubercles. Areola circular, depressed; boss smooth; mamelon small, perforated. Miliary space wide, covered with numerous small granules.

Dimensions.—Height, $1\frac{1}{4}$ inches; width, $2\frac{1}{4}$ inches.

Description.—A large portion of the test of this beautiful species is in an excellent state of preservation. All of the characteristic features, with the exception of those relating to the apical disk and mouth edges, are clearly shown. The test, however, is somewhat compressed, so that the original form can not be with certainty made out. The ambulacral areas are narrow and slightly flexuous. Between the poriferous avenues, which are narrow and depressed, are four rows of granules of nearly equal size which directly at the ambitus are increased to six,

while toward both apical disk and mouth opening they are reduced to two. Irregularly scattered among the rows of granules are others smaller in size. The pores are oval and separated by transverse elevations that partially encircle the openings, leaving a depression between each pair (Pl. VII, Fig. 1*c*).

The interambulacral plates are wide and bear large circular tubercles (Pl. VII, Fig. 1*d*). The areola of each tubercle is radially ridged, deeply depressed, and surrounded by a row of mammilated granules. The boss is slightly elevated above the level of the plate, and presents a smooth and sharp ridge around the small perforated mamelon (Pl. VII, Fig. 1*c*). The miliary space is wide and thickly set with small elevated granules of equal size. The apical disk and mouth edges are lacking.

Related forms.—At first sight this species shows strong points of similarity with *C. sceptrifera* Mantell from the White Chalk of England, although the arrangement of granules in the ambulacral area is different. The areola of *C. sceptrifera* is described as smooth, while that of *C. texanus* is clearly ridged radially. The only related form reported from Texas is *Leiocidaris hemigranosus*, formerly referred to *Cidaris*, but which, as will be shown, does not belong to that genus. *Cidaris Branneri*, from Brazil, described by White, is allied to *C. texanus*, although presenting differences in the character of the areola and arrangement of granules in both the ambulacral and interambulacral areas.

Locality and geological horizon.—This form is found in the Washita formation of the Comanche series (lower Cretaceous) of Bexar county, Texas.

Collection.—U. S. National Museum.

CIDARIS WALCOTTI Clark.

Plate VI, Figs. 4*a–d*

Cidaris Walcotti Clark, 1891. Johns Hopkins University Circulars, No. 87, p. 75.

Determinative characters.—Test small, inflated. Ambulacral areas narrow, sinuous, with four rows of granules between the depressed poriferous avenues. Interambulacral areas broad; each tubercle with depressed circular areola, smooth boss and small imperforate mamelon. Miliary space wide, thickly covered with small granules.

Dimensions.—Height, 1 inch (?). Width, 1½ inches (?).

Description.—The fragments of this form examined are sufficiently distinctive to separate it from other species. A nearly complete interambulacral area, with the adjoining ambulacra, shows that the test of the species is small and in a marked degree inflated (Pl. VI, Fig. 4*a*).

The ambulacral areas are narrow, slightly sinuous, and provided with four nearly equal rows of granules between the poriferous avenues (Pl. VI, Fig. 4*c*). At times additional granules are irregularly interspersed. The poriferous avenues themselves are narrow, deeply depressed, and slightly sinuous. The pores are round, with funnel-shaped openings,

produced by the intersecting ridges. These ridges, which separate the individual pores and the pore pairs, give a lattice-like appearance to the poriferous zones.

The interambulacral plates are moderately large. On account of the indistinctly marked sutures the small tubercles and numerous granules cause a very even surface over the entire interambulacral area (Pl. VI, Fig. 4*b*). The tubercles are circular and stand nearer the outer margin of the plates than the inner. The areolas are deeply depressed, the central portion but slightly exceeding the margin in height. The boss is smooth and stands but little above the level of the plate. The mamelon is imperforate (Pl. VI, Fig. 4*d*). The wide miliary space is covered with a large number of irregularly arranged granules of equal size. The broken specimens afford no information as to the character of the apical disk or mouth edges.

Related forms.—This species is very readily separated from *C. splendens*, the only other representative of this genus thus far reported from the Atlantic Coast Cretaceous, in possessing imperforate mamelons and wide miliary spaces, over which the granules are regularly scattered. The even surface of the test is likewise a distinguishing feature.

Locality and geological horizon.—The specimens of this form examined by the writer were found associated with *C. splendens* in the yellow limestone of the middle marl bed (upper Cretaceous), of Timber creek, New Jersey.

Collection.—Philadelphia Academy of Natural Sciences.

LEIOCIDARIS Desor.

Leiocidaris hemigranosus (Shumard).

Plate VII, Figs. 2*a–d*. Plate VIII, Figs. 1*a–b*. Plate IX, Fig. 1*a–c*.

Cidaris hemigranosus Shumard, 1860. St. Louis, Acad. Sci. Trans., vol. 1, p. 609.
Cidaris hemigranosus Meek, 1864. Smiths. Misc. Coll. (vol. 7, 177), p. 2.
Cidaris hemigranosus White, 1883. U. S. Geol. and Geog. Surv. of the Territories, 12th Ann. Rept. for 1878, p. 38, Pl. 18, Figs. 2*a–b*.
Leiocidaris hemigranosus Clark, 1891. Johns Hopkins University Circulars, No. 87, p. 75.

Determinative characters.—Test very large, subspherical. Ambulacral areas narrow, sinuous, with six rows of granules in the middle. Poriferous avenues wide, deeply depressed. Pores of each pair united by clearly defined furrow. Interambulacral areas broad. Tubercles very large; areola circular or slightly polygonal, depressed; boss smooth; mamelon large, perforated. Miliary space covered with large scattered oval granules. Sutures clearly marked, depressed.

Dimensions.—Height, 2½ inches; width, 3¾ inches.

Description.—This form, which was quite fully described by Shumard in 1860, but not figured, was incorrectly referred to the genus *Cidaris*,

from which it is separated by the presence of furrows uniting the pores of each pair. In this respect it is a typical representative of the genus *Leiocidaris* of Desor. A very good illustration is given by Dr. White in the Twelfth Annual Report for 1878 of the U. S. Geological and Geographical Survey of the Territories, although necessarily, from the size of the figure, the furrows connecting the pores are not very distinctly shown. This species is the largest echinoid known from the Texas Cretaceous, and, with possibly a single exception, the largest from the American Mesozoic. In one unusually fine specimen obtained from Prof. R. T. Hill the test is subspherical, although considerably broader and more flattened on the oral than aboral side.[1]

The ambulacral areas are narrow and sinuous, with six rows of granules between the poriferous avenues (Pl. VII, Fig. 2*b*). The regular arrangement of the granules is not persistent, the number being increased irregularly near the middle of the column and somewhat reduced toward the apical disk and the mouth opening. The poriferous avenues are wide and deeply depressed, the pores of each pair being united by a shallow furrow.

The interambulacral areas are wide and the plates of massive size (Pl. VII, Fig. 2*a*). The tubercles occupy the center of the plates and are large and prominent. The areolas are deeply depressed, subcircular or slightly polygonal, and occupy more than half of the greatest diameter of the plates. On all the specimens examined the areolas show perfectly smooth surfaces, although Shumard mentions the occurrence of radiating ridges. Toward the center each areola rises to form the boss, which is provided marginally with a sharp smooth ridge. The mamelon is large, subspherical, with a deep perforation upon its summit (Pl. VII, Fig. 2*c*). The miliary space is wide and covered with large, irregularly-shaped and flattened granules, some round and some oval in form. Interspersed among these are much smaller granules, which increase in number along the margin of the plates. The apical disk and mouth edges are wanting.

Related forms.—This species is readily separated from any hitherto described from American or European strata. Its characters are well defined and distinctive.

Locality and geological horizon.—Shumard says that it is found "in the Washita limestone [Comanche series (lower Cretaceous)], forming the upper part of the Bluff of Red river, Lamar county, and 10 miles above the mouth of Kiamesha creek, at both localities associated with *Ostrea quadriplicata*." This places it in the Denison beds. It has only been reported from Texas.

Collections.—U. S. National Museum; Prof. R. T. Hill.

[1] A much more perfect specimen (Pl. IX, Figs. 1*a–c*) has been examined by the writer since the above description was prepared.

SALENIDÆ.

Test spheroidal or depressed. Ambulacral areas narrow, straight or flexuous; poriferous zones narrow; pores round, unigeminal, often increased in number toward the mouth opening. Interambulacral areas broad, with two rows of primary tubercles. Apical disk large and prominent. Mouth opening large, with incisions at regular intervals. Anal opening eccentric.

SALENIA Gray.

SALENIA TEXANA Credner.

Plate x, Figs. 1*a–h*.

Cidaris diatretum Giebel, 1853. Jahresber. d. Naturw. Vereins in Halle, 1852, p. 374, Pl. 7, Fig. 2.

Salenia texana Credner, 1875. Zeitschr. f. d. Ges. Naturw., XLVI, pp. 105–116, Pl. V, Figs. 1–6.

Salenia texana Clark, 1891. Johns Hopkins University Circulars, No. 87, p. 75.

Determinative characters.—Test subglobose; upper surface convex; sides inflated; under surface flat. Ambulacra narrow, flexuous, with two rows of mammillated granules in each area; poriferous zones flexed; pores unigeminal. Interambulacral areas wide, with two rows of alternating plates, six in each row. Apical disk large, convex, subcircular; anal opening prominent. Mouth opening moderately large.

Dimensions.—Height, $\frac{3}{4}$ inch; transverse diameter, 1 inch.

Description.—Credner in the Zeitschrift für die gesammten Naturwissenschaften zu Berlin for 1876 presents the first complete diagnosis of a North American Mesozoic echinoid, in the detailed descriptions accorded the present species. Its reference by Professor Giebel in 1852 to *Cidaris diatretum* (=*Pseudodiadema diatretum*) is shown from the carefully prepared specimens to have been erroneous.

The test is subspherical when complete, but in the specimens examined is generally somewhat flattened, both actinally and abactinally. The lower surface is slightly concave in the vicinity of the mouth opening. The sides are inflated, presenting a rounded surface which is fuller above than below (Pl. x, Fig. 1*c*).

The ambulacral areas are narrow, increasing gradually in width from the apical disk to the mouth opening. Two rows of mammillated granules, twenty-four to twenty-six in each, occupy the middle of each area. Very minute granules extend in a line between the rows and in the vicinity of the mouth opening surround the larger granules themselves. The poriferous zones are narrow and flexuous and the pores are regularly arranged in a unigeminal series; near the mouth opening they are slightly more crowded. The most pronounced flexure is opposite the second interambulacral plate from the apical disk. Toward the mouth opening the zones become nearly straight (Pl. x, Figs. 1*e*, 1*f*).

The interambulacral areas are broad, and formed of two alternating rows of broad plates, six in each row (Pl. x, Fig. 1*d*). The tubercles increase rapidly in size from the mouth edges, where they are scarcely larger than the mamillated granules of the ambulacral areas. The areolas are large, and surrounded by mamillated granules of various sizes, that are crowded together along the inner edge of the plates. Between the larger granules are numerous minute granules. The areola rises to a prominent boss, that is deeply crenulated, and bears an imperforate mamelon (Pl. x, Fig. 1*h*).

The apical disk is very large, convex, subcircular, with radiating ridges that extend from the ovarial openings of each plate and unite with similar ridges of adjacent plates. Small punctures are found at the angles of the plates and intermediate between them (Pl. x, Fig. 1*g*). The subanal plate is situated before the anal opening, and occupies the center of the disk. The anal opening is subelliptical, rounded anteriorly, angular posteriorly, and slightly elevated at the border.

The under surface is flat and the mouth opening large, covering nearly one-half the diameter of the test. The mouth opening is circular, with ten incisions upon the edge that divide it into nearly equal-sized lobes (Pl. x, Fig. 1*b*).

Related forms.—Credner, in discussing the affinities of this form, considers it to be closely related to *Salenia petalifera* Defr., and *S. Desori* Wright. It is somewhat more elevated than *S. petalifera*, and the radial ridges on the apical disk are less pronounced on the latter than on the former. The ocular plates also enter less compactly into the composition of the disk in the latter species. In *S. Desori*, on the other hand, there is a wider difference, both in the character of the test plates and the decorations of the apical disk. With *S. scutigera* Gray it also shows some points in common.

Locality and geological horizon.—This form is from Cileola, Comanche spring, Texas, in the Washita formation of the Comanche series (lower Cretaceous).

Collections.—U. S. National Museum; Boston Society of Natural History.

SALENIA TUMIDULA Clark.

Plate XI, Figs. 1*a–j*.

Salenia tumidula Clark, 1891. Johns Hopkins University Circulars, No. 87, p. 75.

Determinative characters.—Test small, subglobose; outline of upper surface regularly convex. Ambulacral areas narrow, nearly straight, with two rows of mammillated granules between the pore pairs; poriferous zones slightly flexed; pores unigeminal. Interambulacral areas wide, composed of two alternating rows of five or six plates. Apical disk large, regularly convex, subcircular; anal opening slightly elevated. Mouth opening small.

Dimensions.—Height, ⅜ inch; transverse diameter, ½ inch.

Description.—The perfectly preserved specimens of this beautiful species admit of a determination of all the details of structure.

The general form of the test is subglobose. The sides are inflated and regularly curved, rising into a convex upper surface, from which the anal opening projects but slightly (Pl. XI, Fig. 1*c*). The lower surface is quite flat, and toward the mouth opening slightly depressed.

The ambulacral areas are rather broad, increasing in width from the apical disk to the mouth edges (Pl. XI, Fig. 1*f*). Extending along the center of each area are two rows of mammillated granules, fifteen or sixteen in each row, between which are other minute granules. The poriferous zones are narrow and nearly straight; the pores round, regularly arranged in a unigeminal series, and largest in the middle of the column.

The interambulacral areas consist of two rows of alternating plates, five or six in each row (Pl. XI, Fig. 1*d*). The larger tubercles diminish rapidly in size toward the mouth edges, and are very indistinct on the plates bordering the same. Each areola is large and circular, the boss crenulated, and the mamelon flattened and imperforate (Pl. XI, Fig. 1*j*). The miliary space is bordered with oval granules of irregular size and arrangement, although most numerous between the rows of tubercles. The sutures of the plates are very indistinctly marked.

The apical disk is prominent, subcircular, with a regularly curved convex surface, from which the anal aperture projects but slightly. The granular decorations of the surface often coalesce and appear as broken ridges extending radially from the five openings in the genital plates (Pl. XI, Fig. 1*g*). The anal opening is oval, slightly pointed below, and projects but slightly above the level of the apical disk. It is bordered by a flange-like edge that is formed of the anal and two genital plates.

The mouth opening is small, occupying scarcely two-fifths of the diameter of the test. Ten incisions divide the edge into lobes, the ambulacral lobes projecting the farther (Pl. XI, Fig. 1*i*).

Related forms.—The identity of this species is readily established by the straight poriferous zones and peculiar decorations of the apical disk. The number of mammillated granules in the ambulacral areas is less than in *S. texana*, while the oval granules of the interambulacral areas are readily distinguishable from the round forms of *S. bellula*.

The anal aperture also projects far less than in *S. texana*, although in this respect it is not unlike *S. bellula*.

Locality and geological horizon.—This species is from the yellow limestone of the middle marl bed (upper Cretaceous) of Timber creek, New Jersey.

Collection.—Philadelphia Academy of Natural Sciences; Johns Hopkins University

SALENIA BELLULA Clark.

Plate XI, Figs. 2*a–g*.

Salenia bellula Clark, 1891. Johns Hopkins University Circulars, No. 87, p. 75.

Determinative characters.—Test small, compressed, circular; upper surface convex; sides inflated; under surface flat. Ambulacral areas rather broad, nearly straight, with two rows of granules in each row; poriferous zones broad, very slightly flexed; pores round, unigeminal. Interambulacral areas wide. Apical disk convex and nearly circular. Mouth opening small.

Dimensions.—Height, $\frac{1}{2}$ inch; transverse diameter, $\frac{5}{16}$ inch.

Description.—This *Salenia* is a very rare form, only a few specimens having come under the notice of the writer, yet from certain peculiarities of outline and structure it is not to be confounded with other species heretofore described.

In general outline the test is somewhat flattened; the upper surface is regularly convex, the sides are inflated, the lower surface is flat or slightly concave at the mouth opening.

The ambulacral areas are prominent and change but slightly in width from the apical disk to the mouth edges. Two rows of mammillated granules, fifteen in each, occupy the center of each area.

The interambulacral areas are wide and consist of two rows of alternating plates, five or six in each. The tubercles are prominent, but decrease rapidly in size toward the mouth edges. The areola is of moderate size, the boss narrow and indistinctly crenulated, and the mamelon small, flattened, and imperforate (Pl. XI, Fig. 2*g*). An indistinct circle of mammillated granules surrounds each tubercle. They unite to form a sinuous double series between the rows of tubercles. Between the larger granules are scattered irregularly numerous small granules that are crowded together along the central line of the interambulacral area (Pl. XI, Fig. 2*d*).

The apical disk is slightly convex, the anal opening interfering but little with the regularity of the curved surface. The anal opening is subcircular, with a flange-like rim. The plates are decorated with oval granules that are arranged in radial rows extending from the opening of each genital plate and unite with corresponding rows of adjacent plates at the suture (Pl. XI, Fig. 2*f*).

The mouth opening is small, being but one-third of the transverse diameter of the test. Ten weak incisions divide the edges into lobes that are nearly of equal size (Pl. XI, Fig. 2*b*).

Related forms.—This species is quite distinct from *Salenia texana* or *S. tumidula*, and at the same time does not admit of reference to any of the European species. It is most closely related to *S. tumidula*, but is more compressed, has a differently shaped and decorated apical disk, and has round and mammillated granules in the miliary space, while those of *S. tumidula* are characteristically oval.

Locality and geological horizon.—This species, like *S. tumidula*, is only found in the yellow limestone of the middle marl bed (upper Cretaceous) of Timber creek, New Jersey.

Collections.—Philadelphia Academy of Natural Sciences; American Museum of Natural History, New York.

DIADEMATIDÆ.

Test more or less spheroidal. Ambulacral areas broad, at times approaching the interambulacral in width. The ambulacral plates are generally compound; the pores unigeminal, increasing oftentimes in the vicinity of the peristome. The mouth opening is large, with deep incisions, and provided near the margins with well-developed auriculæ. The spines are frequently large and variable in shape.

HEMICIDARIS Agassiz.

Hemicidaris intumescens Clark.

Plate XII, Figs. 1*a–i*.

Determinative characters.—Test spheroidal, upper surface inflated, lower surface flat. Ambulacral areas moderately broad, increasing in width from the apical disk to the mouth edges. The tubercles at the peristome are nearly equal in size to those of the interambulacral areas, but become greatly reduced in passing from the ambitus to the apical disk. Interambulacral areas rather wide, with two rows of large tubercles. Miliary space wide, covered with numerous granules. Mouth opening moderately wide, with deep incisions.

Dimensions.—Height, ½ inch; transverse diameter, ¾ inch.

Description.—The very perfectly preserved molds of this species permit the taking in gutta-percha of all the details of form and structure. As the only representative of this genus in American deposits it possesses considerable interest. The test is of moderate size, with a convex and slightly inflated upper surface and nearly flat lower surface. The slightly flexuous ambulacral areas broaden from the region of the apical disk toward the ambitus and slightly contract again before the peristome is reached. The tubercles are prominent in the lower part of the column, where several pairs attain a size nearly equal to those of the interambulacral areas. Minute perforated granules succeed them above and continue as a double row to the apical disk. The poriferous zones are slightly flexuous, and the small pores are unigeminally arranged, although somewhat increased in the vicinity of the mouth edges.

The interambulacral areas are from three to four times the width of the ambulacral at the ambitus. The two rows of medium sized tubercles occupy the center of the plates; the areola is circular and slightly elevated; the boss deeply crenulated, and the mamelon distinctly per-

forated. There are about eight primary tubercles in each row. The apical disk is rather large, although not sufficiently well preserved to admit of a determination of the individual plates.

The mouth opening is small and occupies scarcely one-half of the diameter of the test. It is deeply notched, the lobes being nearly equal in size.

Related forms.—The present species of Hemicidaris is the only representative of the genus known from American deposits. A comparison with European species fails to identify it with any described forms.

Locality and geological horizon.—This species is from the Jurassic strata of Taylorsville, California.

Collection.—U. S. National Museum.

PSEUDODIADEMA Desor.

Pseudodiadema Emersoni Clark.

Plate XII, Figs 2*a–e*.

Determinative characters.—Test circular, depressed. Ambulacral areas straight and prominent; poriferous zones narrow; pores unigeminal. Interambulacral areas not quite twice the width of the ambulacral, with two rows of large tubercles, eight or nine in each row. Mouth opening wide.

Dimensions.—Height, $\frac{1}{4}$ inch; transverse diameter, $\frac{3}{4}$ inch (?).

Description.—The beautifully preserved molds of this interesting form were collected by Prof. Hyatt from the Jurassic beds of Taylorsville, California. The gutta percha casts from which the drawings were made represent very perfectly all the details of structure. The test is nearly circular, the prominent ambulacral areas giving it a slightly subpentagonal outline. The ambulacral areas are rather more than one-half the width of the interambulacral, and support two rows of primary tubercles somewhat smaller than the interambulacral tubercles. There are nine or ten in each row. Between the tubercles are numerous granules that are arranged in an undulating line between the rows and along the margin. They nearly disappear between the tubercles of the same series. Toward the apical disk the tubercles are greatly reduced in size. The pores are unigeminal, there being three or four opposite each ambulacral plate.

The interambulacral areas bear two rows of primary tubercles, eight or nine in each, that are only slightly larger than those of the ambulacral areas. They increase from the peristome to the ambitus, after which they rapidly decrease in size. The areolas are nearly confluent above and below, broader than long, and rise into prominent bosses that are not deeply crenulated. The mamelon is distinctly perforated. The miliary space is covered with granules of different sizes. There are no secondary tubercles developed near the mouth opening. The lower sur-

face is flat, the mouth opening large and deeply notched; the ambulacral lobes larger than the interambulacral. The apical disk is not preserved.

Related forms.—As the only Pseudodiadema in the Jurassic of America it is unique, while its identity with any European form is very doubtful.

It closely resembles *P. Baileyi*, from England, in many particulars, but it is a less depressed form, with more rounded sides and more numerous granules in the miliary space.

Locality and geological horizon.—This species is found in the Jurassic beds of Taylorsville, California, and is named in honor of Prof. B. K. Emerson, of Amherst College, from whom the writer received his first instructions in geology and paleontology.

Collection.—U. S. National Museum.

PSEUDODIADEMA DIATRETUM (Morton).

Plate XIII, Figs. 1*a–f*.

Cidaris diatretum Morton, 1833. Am. Jour. Sci., 1st ser., vol. 23, p. 294.
Cidarites diatretum Morton, 1834. Synop. Organ. Remains, Cretaceous, p. 75, Pl. 10, Fig. 10.
Cidaris diatretum Bronn, 1848, Index Pal., vol. 1, p. 298.
Pseudodiadema diatretum Desor, 1858. Synopsis des Échinides fossiles, p. 73.
Cidaris diatretum Gabb, 1859. Cat. Invert. Fossils, Cretaceous, p. 18.
Pseudodiadema diatretum Cotteau, 1862–'67. Paléont. française, vol. 7, p. 519.
Pseudodiadema diatretum Meek, 1864. Smith. Misc. Coll., vol. 7 (177), p. 2.
Pseudodiadema diatretum Conrad, 1868. Geol. of N. J., Appendix, p. 722.
Cidaris clavigera Credner, 1870. Zeitschr. d. deutsch. geol. Gesells., vol. 22, p. 218.
Cidaris sceptrifera Credner, 1870. Zeitschr. d. deutsch. geol. Gesells., vol. 22, p. 218.
Pseudodiadema diatretum Clark, 1891. Johns Hopkins University Circulars, No. 87, p. 75.

Determinative characters.—Test circular, convex above, concave below, sides inflated. Ambulacra wide, sinuous, with two rows of tubercles, that are large at the ambitus and decrease toward the poles; poriferous zones narrow, sinuous. Interambulacra with two rows of primary tubercles and several irregular rows of secondary tubercles. Mouth opening narrow, about one-third the diameter of the test.

Dimensions.—Height, ½ inch; transverse diameter, 1¼ inches.

Description.—The specimens of this species vary greatly in size, the full-grown forms being moderately large. The test is circular, depressed, slightly convex above, concave below. The sides are inflated (Pl. XIII, Fig. 1*b*).

The ambulacral areas are wide, slightly raised, and furnished with two rows of tubercles, thirteen to fourteen in each row. They are large and prominent at the ambitus, but decrease gradually toward the poles. The broad areolas, that are sharply depressed in their marginal portions, are striated by faint radial ridges on the outer sides. At the upper and inner angle of each plate is a small secondary tubercle, while irregularly scattered over the other portions of the plates are

smaller tubercles, and between them minute granules. The poriferous zones are slightly flexed, the pores of each plate being disposed in curved form about the margin (Pl. XIII, Fig. 1*d*). Although there are generally three pairs of pores on each plate, four pairs are not infrequent near the ambitus (Pl. XIII, Fig. 1*c*).

The interambulacral areas are about one and one-half times the width of the ambulacral, and have two rows of tubercles somewhat larger than those of the latter. There are, in addition, several irregular rows of secondary tubercles, of various sizes, that are most numerous between the rows of primary tubercles and the poriferous zones. Sparsely scattered over the interambulacral space are flattened granules (Pl. XIII, Fig. 1*c*).

The primary tubercles of both the ambulacral and interambulacral areas have wide circular areolas, elevated and deeply crenulated bosses, and distinctly perforated mamelons (Pl. XIII, Fig. 1*f*).

The mouth opening is narrow, reaching scarcely one-third the diameter of the test. The incisions of the margin are weak (Pl. XIII, Fig. 1*a*).

The discal opening is subpentagonal.

Related forms.—This species resembles in some particulars *Pseudodiadema ornatum* Goldfuss, of the Cretaceous of Europe, but the latter form has a different arrangement of the secondary tubercles and granules and lacks the radial striation upon the areolas.

Locality and geological horizon.—*Pseudodiadema diatretum* is from the yellow limestone of the middle marl bed (upper Cretaceous) of Timber creek, New Jersey.

Collections.—Philadelphia Academy of Natural Sciences; American Museum of Natural History, New York.

PSEUDODIADEMA TEXANUM (Roemer).

Plate XIII, Figs 2*a–b*. Plate XIV, Figs. 1*a–g*.

Diadema texanum Roemer, 1852. Die Kreidebildungen von Texas, p. 82, Pl. 10, Fig. 5.
Pseudodiadema texanum Desor, 1858. Synop. des Échinides fossiles, p. 72.
Diadema texanum Gabb, 1859. Cat. Invert. Fossils, Cretaceous, p. 19.
Pseudodiadema texanum Meek, 1864. Smith Misc. Coll. vol. 7 (177), p. 2.
Pseudodiadema Roemeri Clark, 1891. Johns Hopkins University Circulars, No. 87, p. 75.

Determinative characters.—Test small, circular, depressed; sides inflated; upper and lower surfaces about equally flattened. Ambulacra narrow, with two rows of primary tubercles, eleven or twelve in each row; poriferous zones narrow, pores unigeminal. Interambulacra wide, with two rows of primary tubercles of larger size than those of the ambulacra. Mouth opening wide, covering nearly one-half the diameter of the test. Discal opening subcircular, with deep incision in right anterior ambulacrum.

Dimensions.—Transverse diameter, $\frac{5}{8}$ inch; height, $\frac{3}{16}$ inch.

Description.—This form, described by Roemer, in 1852, as *Diadema texanum*, was assigned a new name (*P. Roemeri*) by the writer in his

preliminary report,[1] when *Cyphosoma texanum* of the same author was referred to *Pseudodiadema*. The reference of the latter form to *Diplopodia*, in the present report, makes it possible to return to the earlier name for the present species.

The test is circular, very much depressed on both the upper and lower surfaces and inflated at the sides (Pl. XIV, Fig. 1*c*).

The ambulacral areas are narrow and lanceolate. They bear two rows of tubercles, eleven or twelve in each row, that decrease rapidly in size from the ambitus to the poles (Pl. XIV, Fig. 1*e*; Pl. XIII, Fig. 2*b*). The areolas are circular, the bosses stout and prominent, the mamelons distinctly perforated (Pl. XIV, Fig. 1*g*). Small secondary tubercles are irregularly dispersed between the rows of primary tubercles. A few scattered granules surround the same. The poriferous zones are unigeminal throughout, though the pores show a slight tendency to increase at the peristome.

The interambulacral areas are about twice the width of the ambulacral. There are two rows of primary tubercles, nine or ten in each row, that decrease in size from the ambitus to the poles (Pl. XIV, Fig. 1*d*; Pl. XIII, Fig. 2*a*). The areolas are depressed, circular, and distinctly outlined, the bosses elevated and deeply crenulated, the mamelons large and deeply perforated. Small secondary tubercles surround the primary tubercles, between which are interspersed minute granules (Pl. XIV, Fig. 1*f*).

The mouth opening is wide, covering nearly one-half of the diameter of the test. Ten incisions produce well-defined lobes at regular intervals (Pl. XIV, Fig. 1*b*). The discal opening is large and subcircular, with a deep incision in the right anterior ambulacrum (Pl. XIV, Fig. 1*a*).

Related forms.—Both Roemer and Desor mention the similarity of this species to *P. tenue*, of the Cenomanian of Europe, from which, however, it is separated by its smaller tubercles and more numerous granules.

Locality and geological horizon.—This important species is common in the Fredericksburg formation of the Comanche series (lower Cretaceous) of Texas, and is found at Fredericksburg and near San Saba valley.

Collection.—U. S. National Museum.

DIPLOPODIA McCoy.

DIPLOPODIA TEXANUM (Roemer).

Plate XV, Figs. 1*a–f*; Plate XVI, Figs. 1*a–d*.

Diadema texanum Roemer, 1849. Texas, etc., p. 392.

Cyphosoma texanum Roemer, 1852. Die Kreidebildungen von Texas, p. 82, Pl. 10, Fig. 6.

Cyphosoma texanum Conrad, 1857. U. S. and Mex. Bound. Surv. Rept., vol. 1, pt. 2, p. 145, Pl. 1, Fig. 3.

Phymosoma texanum Desor, 1858. Synopsis des Échinides fossiles, p. 90.

[1] Johns Hopkins University Circulars, 1891, No. 87, pp. 75–77.

Cyphosoma texanum Gabb, 1859. Cat. Invert. Fossils, Cretaceous, p. 18.
Cyphosoma texanum Gabb, 1869. California Geol. Surv., Paleontology, vol. 2, p. 276.
Pseudodiadema texanum Clark, 1891. Johns Hopkins University Circulars, No. 87, p. 75.

Determinative characters.—Test large, subcircular; sides inflated; upper surface elevated; lower surface depressed, concave. Ambulacra prominent, with two rows of primary tubercles; poriferous zones broad above, narrow below; pores in single pairs from peristome to ambitus, beyond which to the apical disk they are bigeminal. Interambulacra wide, with four rows of primary tubercles at the ambitus, which become reduced to two at the poles. Mouth opening wide, about two-fifths the diameter of the test. Discal opening large, subpentagonal.

Dimensions.—Transverse diameter, $1\frac{3}{4}$ inches; height, $\frac{7}{8}$ inch.

Description.—This species was first described by Roemer, in 1849, in Texas, etc., as *Diadema texanum*, but subsequently, in 1852, referred to *Cyphosoma*. Although the perforated mamelons are not always shown with distinctness at the first glance, they are sufficiently numerous upon careful inspection to warrant the removal of this form from the genus *Cyphosoma*.

The test is large, subcircular and elevated (Pl. XV, Fig. 1*c*). The sides are inflated, and the upper surface elevated and convex. The base is depressed and concave.

The ambulacral areas are broad and lanceolate. They have two rows of primary tubercles, fourteen or fifteen in each series, that are large at the ambitus and decrease gradually toward the poles (Pl. XV, Fig. 1*d*). A circle of scattered granules surround the narrow areolas. The poriferous zones are broad upon the upper surface, but below the ambitus are very much narrowed. The pores are in single pairs below the ambitus, except directly at the mouth edges, where they become greatly increased, as shown in Plate XVI, Fig. 1*a*. From the ambitus to the apical disk they are bigeminal (Pl. XV, Fig. 1*c*), a character which Duncan, in his recent revision of the Echinoidea, considers of generic importance and sufficient ground for a separation of Diplopodia from Pseudodiadema.

The interambulacral areas are about one and one-half times the width of the ambulacral at the ambitus. There are four rows of primary tubercles at the ambitus (Pl. XV, Fig. 1*f*), which become reduced to two in the vicinity of the apical disk and mouth edges (Pl. XVI, Fig. 1*b*, 1*c*). In the center of the column the tubercles of the four rows are of about equal size, but those of the outer rows become much more rapidly reduced in size toward the poles. Small secondary tubercles are found on the outer margin of the plates, while irregularly scattered granules cover the space between the tubercles. A broad depression occurs along the line of the central suture in the vicinity of the discal opening.

The mouth opening is circular, but is broken by distinct incisions. Its diameter is about two-fifths that of the test (Pl. XV, Fig. 1*b*).

The discal opening is large and subpentagonal (Pl. XV, Fig. 1*a*).

Related forms.—This species is closely allied to or perhaps identical with the form described by D'Orbigny in 1842 from the United States of Colombia under the name of *Echinus Bolivarii*, and later recognized by Gabb in a collection obtained from Peru. As the original description and figures leave some doubt as to the determination of the species, the term *texanum* is retained here.

Locality and geological horizon.—This form is found in the Fredericksburg formation of the Comanche series (lower Cretaceous) of Texas. It is from the Comanche Peak beds, and is reported from Fredericksburg and near the head of the San Saba river.

Collections.—U. S. National Museum; Boston Society of Natural History; Texas Geological Survey; University of Iowa; Prof. Robt. T. Hill.

Diplopodia Hilli Clark.

Plate XVI, Figs. 2*a–g*.

Pseudodiadema Hilli Clark, 1891. Johns Hopkins University Circulars, No. 87, p. 76.

Determinative characters.—Test subpentagonal, depressed; sides inflated; upper and lower surfaces flattened. Ambulacra prominent, straight, with two rows of primary tubercles, twelve or thirteen in each row; poriferous zones narrow, with slight increase in width toward the apical disk; pores in single pairs below but bigeminal on the upper surface. Interambulacra with two rows of primary tubercles of equal size with those of the ambulacra. Mouth opening narrow, circular. Discal opening broad, pentagonal.

Dimensions.—Transverse diameter, $\frac{3}{4}$ inch; height, $\frac{5}{16}$ inch.

Description.—This rare Diplopodia has a subpentagonal outline, the projecting ambulacra occupying the angles. It is depressed on both the upper and lower surfaces, the latter becoming somewhat concave toward the mouth opening. The sides are moderately inflated.

The ambulacra are broad, very prominent, and furnished with two rows of large tubercles, twelve or thirteen in each row, that decrease rapidly from the ambitus toward the apical disk and peristome. The poriferous zones are narrow and lanceolate. The pores are arranged in single pairs on the lower surface, but from the ambitus to the apical disk are increased slightly in number, and near the apical disk become bigeminal (Pl. XVI, Fig. 2*d*). The interambulacral areas are narrow and appear flattened, as compared with the slightly projecting ambulacra. They are provided with two rows of primary tubercles of equal size with those of the ambulacra (Pl. XVI, Fig. 2*f*). There are ten or eleven in each row. The areolas are narrow, circular, and elevated, the bosses prominent and distinctly crenulated, and the mamelons deeply perforated. The tubercles are somewhat widely separated and the intervening space is covered with small secondary tubercles and sparsely scattered granules.

The mouth opening is broad, depressed, and circular. It is divided

by ten incisions into well-defined lobes, those of the ambulacra broader and extending farther into the opening than the others (Pl. XVI, Fig. 2*b*).

The distal opening is pentagonal, the angles occurring at the point of the medial suture of the interambulacra (Pl. XVI, Fig. 2*a*).

Related forms.—*Diplopodia Hilli* appears at first glance closely allied to, if not identical with, *Pseudodiadema texanum*. It is separated from the same, however, by its larger size, subpentagonal form, and increase in number of pores from the ambitus to the apical disk. In this latter particular it is not unlike *D. texanum*, from which, however, it is separated by its smaller size, subpentagonal form, and two instead of four rows of primary tubercles. It is similar to *P. Rhodani* of the European Cretaceous in some particulars, but that form is without the increase in number of pores on the upper surface and likewise possesses more plates in each column.

Locality and geological horizon.—This species is from the Austin chalk (upper Cretaceous) of Texas.

Collections.—U. S. National Museum; Prof. Robt. T. Hill.

COPTOSOMA Desor.

Coptosoma Mortoni (de Loriol).

Plate XVII, Figs. 1*a–c*.

Cyphosoma Mortoni de Loriol, 1887. Recueil Zoologique Suisse, Tome IV, No. 3, pp. 389–391, Pl. XVII, Fig. 2*a–c*.

Determinative characters.—Test circular, depressed. Ambulacra very wide, with two rows of primary tubercles, thirteen in each row, the three or four at the ambitus large and nearly confluent, but diminishing rapidly in size toward either pole; poriferous zones narrow, sinuous; pores unigeminal, those of each pair separated by a granule. Interambulacra with two rows of tubercles, nine or ten in each row. Mouth opening very large.

Dimensions.—Transverse diameter, $\frac{1}{2}$ to $\frac{5}{8}$ inch; height, $\frac{1}{4}$ inch.

Description.—The writer has been unable to obtain a specimen of this species, but the very full description and excellent figures given by de Loriol admit of its satisfactory identification. The description that follows is a translation in nearly every particular of that given by de Loriol. The two specimens in the possession of de Loriol were so deformed that he could not determine the height accurately. The test is circular and depressed. The ambulacral areas are relatively very wide, almost as large as the interambulacral, and bear two rows of large tubercles, thirteen in each row. The first four or five tubercles from the apical disk are far apart and very small. At the ambitus three or four of the tubercles are very large, with nearly confluent areolas (Pl. XVII, Fig. 1*c*), but rapidly diminish in size toward the lower surface, the last four or five being very small and with difficulty distinguished. The areolas, except at the ambitus, are not large.

The bosses are finely crenulated and the mamelons small and imperforate. Upon the lower surface there are large mammillated granules which can be with difficulty distinguished from the primary tubercles. Each areola is also partially surrounded by a circle of small granules that occur most numerously near the line of the central suture. The granules are few in number on the upper surface. The poriferous zones are narrow, slightly sinuous, and composed of small pores without any increase toward the apical disk or mouth opening. A small granule is found between the pores of each pair (Pl. XVII, Fig. 1*c*).

The interambulacral areas bear two rows of primary tubercles that are similar to those of the ambulacra, but larger and less numerous (Pl. XVII, Fig. 1*a*). The lower surface is covered by large mammillated granules that can scarcely be distinguished from the tubercles, and also by numerous small ones. There are few granules on the upper surface. The mouth opening is large, with slight incisions.

Related forms.—This species is most closely related to *Coptosoma speciosum*, but in form and in several details of structure is unlike it. The presence of granules between the pores of the present species is a marked feature.

Locality and geological horizon.—This form is from the Rotten limestone (upper Cretaceous) of Nahalak, Kemper county, Mississippi.

Collection.—P. de Loriol, Switzerland.

COPTOSOMA SPECIOSUM Clark.

Plate XVIII, Figs. 1*a–h*.

Cyphosoma speciosum Clark, 1891. Johns Hopkins University Circulars, No. 87, p. 76.

Determinative characters.—Test circular, inflated at the sides, flattened on the upper and lower surfaces. Ambulacra wide, with two rows of primary tubercles, twelve or thirteen in each, that gradually diminish in size toward the poles; poriferous zones sinuous; pores unigeminal. Interambulacra with two rows of tubercles slightly larger than those of the ambulacra. Mouth opening one-third the diameter of the test.

Dimensions.—Transverse diameter, $\frac{11}{16}$ inch; height, $\frac{3}{8}$ inch.

Description.—This delicate species has a circular test with inflated sides. Both poles are flattened, the lower more than the upper (Pl. XVIII, Fig. 1*b*).

The ambulacral areas are wide and prominent, and bear two rows of large tubercles, twelve or thirteen in each row. The areolas are nearly confluent above and below, and are striated by irregular radiating ridges (Pl. XVIII, Fig. 1*f*). The bosses are deeply crenulated, and the small mamelons are imperforate. Minute tubercles and granules irregularly surround the primary tubercles, occurring in greatest number along the central suture. The poriferous zones are slightly sinuous, the three pore pairs having a curved arrangement on each ambulacral plate.

The interambulacral areas are about one and one-half times as wide as the ambulacral. They have two rows of primary tubercles that are somewhat larger than those of the ambulacra (Pl. XVIII, Fig. 1*d*). The areolas are very large and are confluent above and below. Throughout the greater part of the column the two rows approach each other, but toward the apical disk are widely separated from one another. The smaller tubercles are disposed in rows, with greater or less regularity, on either side of the primary series.

The mouth opening is narrow, occupying a little more than one-third of the diameter of the test. It has an irregular pentagonal outline. The disical opening is large and pentagonal in form. (Pl. XVIII, Fig. 1*a*).

Related forms.—This form is apparently closely related to *Coptosoma Mortoni*, but is more elevated and does not exhibit the granules between the pores.

Locality and geological horizon.—This species is from the yellow limestone of the middle marl bed (upper Cretaceous) of Timber creek, New Jersey.

Collection.—Philadelphia Academy of Natural Sciences.

GONIOPYGUS Agassiz.

GONIOPYGUS ZITTELI Clark.

Plate XVIII, Figs. 2 *a–d*. Plate XIX, Figs. 1 *a–e*.

Goniopygus Zitteli Clark, 1891. Johns Hokins University Circulars, No. 87, p. 76.

Determinative characters.—Test subconoidal, circular in circumference; upper surface elevated; base flattened. Ambulacra broad, with a double row of alternating tubercles, eighteen to twenty in each series; poriferous zones, with a double row of pores, multiplied at the peristome. Interambulacra broader than the ambulacra, with a double row of primary tubercles, ten to twelve in each row. Apical disk prominent, compact. Mouth opening large, with shallow incisions.

Dimensions.—Transverse diameter, 1½ inches; height, 1 inch.

Description.—All the specimens of this species examined by the writer have a distinctly subconical form that is highly characteristic. The upper surface is very much elevated, while the lower is flat and slightly depressed around the mouth edges (Pl. XVIII, Fig. 2*a*).

The ambulacral areas are broad, increasing regularly in width from the apical disk to the ambitus, beyond which they decrease toward the mouth opening (Pl. XIX, Fig. 1*d*). There is a double row of eighteen to twenty tubercles in each area, that rapidly increase in size from the apical disk downward. The pores are arranged in a double row on each poriferous zone except in the vicinity of the mouth edges, where they become suddenly increased in number (Pl. XVIII, Fig. 2 *b*).

The interambulacral areas are about one and one-half times the width of the ambulacral, and each contains a double row of large tubercles,

ten to twelve in each series (Pl. XIX, Fig. 1*c*). These tubercles are considerably larger than those of the ambulacral area, and have wide circular areolas, smooth bosses, and imperforate mamelons (Pl. XVIII, Fig. 2*c*). On the base the tubercles of all the areas are of nearly equal size. The miliary space is wide, very nearly smooth in the upper portions of the column, and sparsely covered with granules toward the mouth edges.

The apical disk is large and compact, the elongated genital plates giving it a star-shaped appearance (Pl. XVIII, Fig. 2*d*). The well-defined ocular plates, wedged into the interspaces, make the entire outline subpentagonal. Each genital plate is angular at the outer extremity and perforated. On the inner edge of the same there is a semicircular depression, in the center of which is a small mammillated tubercle.

The mouth opening is large, covering quite one-half the diameter of the base. It is divided into ten lobes by ten shallow incisions (Pl. XIX, Fig. 1*b*).

Related forms.—This species shows many points of similarity to *Echinus patagonensis*, described by d'Orbigny in 1842, from the Tertiary of southern Patagonia. The margin of d'Orbigny's species is sharper and the apical disk of somewhat different shape. Moreover, if properly referred to the Tertiary, it is undoubtedly a different form. *Echinus andinus*, from the desert of Atacama, described by Philippi in 1860, is likewise closely allied to *G. Zitteli*, though more conical and presenting a different surface decoration of the plates. *Goniopygus major*, from the Cenomanian of Europe, is similar in many particulars, though the pores are not increased around the peristome as in *G. Zitteli*, and the apical disk is of more compact form.

Locality and geological horizon.—*Goniopygus Zitteli* is from the Caprina limestone, a division of the Fredericksburg formation of the Comanche series (lower Cretaceous), and has been collected at many points in Texas, among others Spanish Oak branch, Williamson county, and Round Rock.

Collections.—U. S. National Museum; Texas Geological Survey.

ECHINIDÆ.

Test spheroidal. Ambulacra wide, with two or more rows of primary tubercles; poriferous zones usually trigeminal or polygeminal. Interambulacra with two or more rows of primary tubercles, generally of equal size with those of the ambulacra. Mouth opening large, decagonal. Apical disk composed of ten plates.

PSAMMECHINUS Agassiz.

PSAMMECHINUS CINGULATUS Clark.

Plate XX, Figs. 1*a–i*.

Psammechinus cingulatus Clark, 1891. Johns Hopkins University Circulars, No. 87, p. 76.

Determinative characters.—Test small, hemispherical, with circular circumference; sides inflated; upper surface elevated; base flattened and concave. Ambulacra wide, with two rows of primary tubercles, sixteen or seventeen in each series; poriferous zones depressed, trigeminal. Interambulacra about one and one-half times the width of the ambulacra; plates covered with numerous uncrenulated and imperforate tubercles. Mouth opening large, with ten deep incisions.

Dimensions.—Transverse diameter, $\frac{7}{8}$ inch; height, $\frac{1}{2}$ inch.

Description.—This delicate form, of which two very perfect specimens were examined by the writer, is hemispherical in shape with circular circumference, inflated sides, elevated upper surface, and flattened base. In the vicinity of the mouth opening the lower surface is depressed, producing a slight concavity.

The ambulacral areas are wide and composed of eighteen to twenty plates (Pl. XX, Fig. 1*f*). The lower sixteen or seventeen of each series bear prominent tubercles that occur in a continuous line to the peristome. On either side of the primary tubercles are smaller ones of like shape. The three pore pairs are arranged in semicircular form, the two upper separated from the lower by one of the secondary tubercles (Pl. XX, Fig. 1*g*).

The interambulacral areas are about one and one-half times as wide as the ambulacral and the plates about fifteen in number. Each plate bears a large tubercle in the center, and irregularly arranged about it smaller tubercles of various sizes (Pl. XX, Fig. 1*e*).

The mouth opening is large, with ten deep incisions (Pl. XX, Fig. 1*h*). The apical disk is lacking, but the broken opening is large and pentagonal in form.

Related forms.—This unique species is quite unlike any hitherto described, and is readily characterized by the arrangement of the tubercles and pore pairs. As the only representative of this genus recognized in American deposits it has especial interest.

Locality and geological horizon.—This species is labeled as simply from New Jersey, but in character of preservation is not unlike other specimens from the yellow limestone of the middle marl bed (upper Cretaceous) of Timber creek.

Collection.—Philadelphia Academy of Natural Sciences.

STOMECHINUS Desor.

STOMECHINUS HYATTI Clark.

Plate XXIII, Figs. 1*a–e*.

Determinative characters.—Test high, circumference circular. Ambulacra with four rows of small primary tubercles; poriferous zones wide, trigeminal. Interambulacra with eight or ten rows of tubercles that diminish in number toward apical disk and mouth opening, with a depression along the line of the central suture.

Dimensions.—Height, 1 inch; transverse diameter, 1 inch.

Description.—The single specimen of this interesting Jurassic form has only the cast of a portion of the exterior preserved. The test is high, and the circumference circular or slightly subpentagonal. The sides rise abruptly from the margin (Pl. XXIII, Fig. 1*a*).

The ambulacral areas are about one-half the width of the interambulacral, and preserve a nearly uniform width throughout. There are four rows of tubercles that increase slightly in size from above downward. A depression appears along the line of the central suture. The poriferous zones are wide; the pore pairs are placed in oblique ranks of three, and each rank is separated from that next to it by two small tubercles (Pl. XXIII, Fig. 1*b*).

The interambulacral area is about twice the width of the ambulacral, and the plates of the former are but slightly higher than those of the latter (Pl. XXIII, Fig. 1*c*). Each plate is covered at the widest part of the area with an irregular row of four or five tubercles that are of about equal size. The tubercles of the interambulacral areas are of about the same size as those of the ambulacral. The tubercles are uncrenulated and imperforate. A wide depression extends along the medial line of each interambulacral area according with the position of the central suture.

The regions of the apical disk and mouth opening are largely wanting, but a deep incision shown upon the margin of the latter indicates that it is distinctly lobed throughout.

Related forms.—The American species shows some points of identity with *Stomechinus nudus* Wright of England, though the latter is less elevated, has a sharper marginal angle, and a less regular arrangement of the tubercles.

Locality and geological horizon.—This species is from the Jurassic strata of Taylorsville, California.

Collection.—U. S. National Museum.

PEDINOPSIS Cotteau.

Pedinopsis Pondi Clark.

Plate XXI, Figs. 1*a–b*. Plate XXII, Figs. 1*a–c*.

Determinative characters.—Test large, circular, inflated at the sides, convex on the upper surface. Ambulacra with six rows of tubercles at the ambitus, the two marginal rows complete and the four inner incomplete; poriferous zones broad, bigeminal. Interambulacra with twenty rows of tubercles at the ambitus, which become reduced to four at the margin of the mouth opening; tubercles small, equal, crenulated, and perforated. Mouth opening small, with distinct incisions.

Dimensions.—Transverse diameter, 3½ inches; height, 2¾ inches.

Description.—The single very large specimen of this species examined by the writer has portions of the test in a very perfect state of preservation. The test is large, circular, inflated at the sides, and convex on the upper surface. The lower surface is flattened, with a slight concavity in the region of the mouth opening (Pl. XXII, Fig. 1*a*). The ambulacral areas are wide, and have at the ambitus six rows of tubercles (Pl. XXII, Fig. 1*c*), the two marginal rows alone continuing from the discal opening to the peristome. The four inner rows are incomplete, but of equal size with the outer. The tubercles are finely crenulated and perforated. The poriferous zones are broad and bigeminal (Pl. XXII, Fig. 1*c*), except on the lower surface, where the rows become crowded together. Near the mouth opening they again broaden out and become greatly increased in number at the margin. The pores are small and round. The interambulacral areas are broad and have twenty rows of tubercles at the ambitus, which become reduced to four at the mouth edges (Pl. XXII, Fig. 1*b*). The tubercles are of equal size with those of the ambulacra. Small mammillated granules are found scattered over both the ambulacral and interambulacral plates, together with a fine granulation covering the entire surface.

The mouth opening is small and measures about seven-eighths of an inch in diameter. It has ten distinct incisions in the interambulacra. The discal opening is partially outlined, but is very indistinct.

This species is named for Mr. Edwin J. Pond, of the U. S. Coast and Geodetic Survey, by whom the specimen described by the writer was discovered.

Related forms.—The present species is unlike any described from American or European deposits.

Locality and geological horizon.—The specimen was found on the south bank of Onion creek, Travis county, Texas, about one-fourth mile southwest of the crossing of the Austin and San Antonio wagon road. It is probably from the lower portion of the Austin chalk (upper Cretaceous).

Collection.—Johns Hopkins University.

IRREGULARES.

ECHINOCONIDÆ.

Test circular, elliptical, or pentagonal. Ambulacra narrow; poriferous zones unigeminal, seldom bigeminal. Interambulacra broad; surface covered with small, perforated, and crenulated tubercles, that are larger on the base. Mouth opening central, circular, or decagonal, with jaws and distinct incisions. Apical disk central, composed of ten plates. Anal opening between apical disk and mouth opening.

HOLECTYPUS Desor.

HOLECTYPUS PLANATUS Roemer.

Plate XXIII, Fig. 2*a–f*.

Holectypus planatus Roemer, 1849. Texas, etc., p. 393.
Holectypus planatus Roemer, 1852. Die Kreidebildungen von Texas, p. 84, pl. 10, Fig. 2.
Holectypus planatus Shumard, 1852. Rept. Expl. Red River of La., p. 211.
Holectypus planatus Giebel, 1853. Jahresber. d. Naturw. Ver. in Halle, p. 373.
Holectypus planus Giebel, 1853, ibid.
Holectypus planatus Conrad, 1857. U. S. and Mex. Bound. Surv. Rept. vol. 1, pt. 2, p. 145, pl. 1, Fig. 4.
Holectypus planatus Desor, 1858. Synop. des Échinides fossiles, p. 174.
Holectypus planatus Gabb, 1860. Cat. Invert. Fossils, Cretaceous, p. 18.
Holectygus planatus Meek, 1864. Smith. Misc. Coll., vol. 7 (177), p. 2.
Holectypus planatus Clark, 1891. Johns Hopkins University Circulars, No. 87, p. 76.

Determinative characters.—Test subcircular, subconical, flattened on the under surface. Ambulacra narrow, straight, and somewhat lanceolate, with six irregular rows of tubercles; poriferous zones straight, narrow, unigeminal. Interambulacra wide, plates numerous and narrow, each with a nearly horizontal row of small tubercles. Apical disk small, the madreporite large. Mouth opening small, subcircular. Anal opening large.

Dimensions.—Height, $\frac{3}{4}$ inch; transverse diameter, $1\frac{3}{8}$ inches.

Description.—This very common form, from the Cretaceous of Texas, was first reported by Roemer in "Texas," etc., in 1849, and subsequently, in 1852, more accurately defined and figured. Although wide differences in outline and in the size and arrangements of the tubercles occur, they appear to be rather individual than specific. The majority of the specimens are subcircular; in the case of some, however, distinctly circular, while in that of others clearly pentagonal. The ambitus in some individuals is sharp, in others, rounded, while the upper surface is distinctly elevated at the center with slightly tumid sides. The under surface is flat and slightly depressed in the vicinity of the mouth opening.

The ambulacral areas are narrow, straight, increasing in width toward the ambitus and somewhat lanceolate in form. The poriferous zones are narrow, the pores small and unigeminal. Six rows of small tuber-

cles are found in the broader portion of the areas, which become reduced to four toward the apical disk and mouth edges (Pl. XXIII, Fig. 2*e*).

The interambulacral areas are about three times the width of the ambulacral at the ambitus. The plates are narrow, each with a horizontal row of small tubercles, five or six in a row at the ambitus, but fewer above and below. Each tubercle has a small circular areola, crenulated boss, and perforated mamelon. The tubercles cover the greater portion of the plates, with minute granules interspersed between them (Pl. XXIII, Fig. 2*d*). The tubercles are very much larger on the lower surface, and the difference in size shown between those of the ambulacra and interambulacra on the upper surface disappears.

The apical disk is small. The five ovarial plates are all perforated; the madreporite is of large size and indistinctly separated from the other plates (Pl. XXIII, Fig. 2*f*).

The mouth opening is small, with slight incisions that give a decagonal margin. The large oval anal opening extends from the vicinity of the mouth edges to the ambitus (Pl. XXIII, Fig. 2*b*).

Related forms.—Cotteau has recently described, under the name of *H. Castilloi*, a new species of *Holectypus* from Mexico that is not unlike certain individuals of *H. planatus* examined by the writer. As a sufficient number of intermediate forms has been found to connect all the specimens examined with the type form described by Roemer, no attempt has been made to establish new species. *H. planus* described by Giebel is considered such a variation.

Locality and geological horizon.—This widely distributed form is from the Washita formation of the Comanche series (lower Cretaceous) of Texas. It has been found at Austin, Fredericksburg, and elsewhere.

Collections.—U. S. National Museum; Philadelphia Academy of Natural Sciences; Boston Society of Natural History; Texas Geological Survey; Prof. Robt. T. Hill.

CASSIDULIDÆ AGASSIZ.

Test circular, oval or subpentagonal. Ambulacra simple or petaloid, generally similar. Mouth opening central or subcentral, generally with a pentapetaloid floscelle. Anal opening excentric.

PYRINA Desmoulins emend. de Loriol.

PYRINA PARRYI Hall.

Plate XXIV, Figs. 1*a–k*.

Pyrina Parryi Hall, 1857. U. S. and Mex. Bound. Surv. Rept., vol. 1, pt. 2, p. 144, Pl. 1, Fig. 1–1*d*.
Pyrina Parryi Gabb, 1859. Cat. Invert. Fossils Cretaceous, p. 19.
Pyrina Parryi Meek, 1864. Smith. Misc. Coll., vol. 7 (177), p. 2.
Pyrina Parryi Clark, 1891. Johns Hopkins University Circulars, No. 87, p. 76.

Determinative characters.—Test subpentagonal, broader anteriorly than posteriorly, inflated at the sides, flattened above and below.

Ambulacral areas narrow, unigeminal; both areas covered with minute tubercles.

Mouth opening large, elliptical, oblique. Anal opening oval, supramarginal.

Dimensions.—Length, 1¼ inches; height, ⅝ inch.

Description.—The two specimens originally described by Hall, in the Mexican Boundary Survey Reports, are the only representatives of this interesting species that have been examined by the writer. The test is regular and symmetrical, slightly pentagonal in outline, enlarged anteriorally, contracted posteriorly. The upper surface is convex, though somewhat flattened at the summit. The sides are inflated, the base flattened and slightly depressed in the vicinity of the mouth opening (Pl. XXIV, Figs 1*c*, 1*d*).

The ambulacral areas are narrow and lanceolate; the poriferous zones straight and depressed, the pores small, oval, and unigeminal (Pl. XXIV, Fig. 1*f*). The interambulacral areas are broad and less elevated than the ambulacral. Both the ambulacra and interambulacra support numerous small tubercles, that are larger and more distinct on the lower than the upper surface. Fine microscopic granules are disseminated between the tubercles (Pl. XXIV, Figs. 1*e*, 1*g*).

The mouth opening is large, elliptical, and obliquely situated slightly in front of the center of the base. The anal opening is oval and placed nearly in the center of the posterior margin. The apical disk is small, composed of four ovarial plates, the large right antero-lateral modified to form the madreporite. The five small ocular plates are firmly wedged between the ovarial plates (Pl. XXIV, Fig. 1*h*).

Related forms.—The species just described is the only representative of this genus reported from American strata, and both in form and structural features admits of a ready separation from all European species. It presents some points of similarity with *Pyrina Desmoulinsii* D'Archiac, but is broader posteriorly and less elevated.

Locality and geological horizon.—*Pyrina Parryi* Hall is from the Washita formation of the Comanche series (lower Cretaceous), and in vol. I of the United States and Mexican Boundary Survey Reports is reported from Leon Springs, El Paso Road, Texas.

Collection.—U. S. National Museum.

BOTRIOPYGUS D'Orbigny.

BOTRIOPYGUS ALABAMENSIS Clark.

Plate XXV, Figs. 1*a–f*.

Botriopygus alabamiensis Clark, 1891. Johns Hopkins University Circulars, No. 87, p. 76.

Determinative characters.—Test oblong; more or less depressed on upper surface, highest anteriorly; under surface concave. Ambulacra broad, lanceolate; poriferous zones subpetaloidal above. Interambu-

lacral plates covered with numerous, irregularly distributed tubercles. Apical disk anteriorly situated. Mouth opening small, oblique, forward of the center.

Dimensions.—Length, 2⅝ inches; width, 2⅛ inches; height, 1 inch.

Description.—The single imperfectly preserved specimen of this species, although apparently lacking some of the characteristics of *Botriopygus*, is nevertheless referred to that genus. The test is oblong, considerably depressed on the upper surface, and concave on the base. The apex of the upper surface is forward of the center, making the anterior margin full, the posterior flattened (Pl. XXV, Fig. 1*c*).

The ambulacral areas are broad and lanceolate. They contract appreciably just above the ambitus, giving to the poriferous zones a subpetaloidal form. The pores of the subpetaloidal portions are large and oval, those of the outer rows more elongated than those of the inner and acuminated on their inner margins. The pores of each pair are united by a furrow. The inner portions of ambulacral plates are covered with tubercles that in the broadest portion of the subpetaloidal areas reach five or six in number (Pl. XXV, Fig. 1*c*). Below the subpetaloidal areas the pores recede from the outer margin of the plates. Those of each pair are close together, small, and nearly round. The plates also become broader (Pl. XXV, Fig. 1*d*).

The interambulacral plates are large and covered with numerous, irregularly arranged tubercles. A microscopic granulation covers the intertubercular space (Pl. XXV, Fig. 1*f*).

The position of the apical disk is forward of the center of the upper surface, although none of the plates are preserved on the specimen examined. The mouth opening is small and obliquely placed slightly in front of the center of the base.

Related forms.—Gabb describes a species of *Botriopygus* from Peru under the name of *B. elevatus* that is not unlike *B. alabamensis* in many particulars, though the American species is larger, less rounded anteriorly, and has a more depressed posterior margin.

Locality and geological horizon.—This form is from the Ripley group (upper Cretaceous) of Alabama. Its exact locality is unknown.

Collection.—Philadelphia Academy of Natural Sciences.

ECHINOBRISSUS Breyn.

Echinobrissus expansus Clark.

Plate XXVI, Figs. 1*a–g*.

Echinobrissus expansus Clark, 1891. Johns Hopkins University Circulars, No. 87, p. 76.

Determinative characters.—Test subquadrate, broader posteriorly, moderately convex on upper surface, concave on the base. Ambulacra narrowly lanceolate. Anal opening large, supramarginal; anal sulcus broad, deep, extending from near the apex to the ambitus. Mouth opening large, situated in front of the middle of the base.

Dimensions.—Length, 1⅛ inches; width, 1⅛ inches; height, ½ inch.

Description.—This typical Echinobrissus is of moderate size, somewhat depressed above, and subquadrate in marginal outline. The posterior portion is broader than the anterior and distinctly lobed. The base is concave.

The ambulacral areas are narrowly lanceolate, and on the upper surface the poriferous zones are subpetaloidal (Pl. XXVI, Fig. 1*a*). The inner rows of pores are round, the outer oval, with acuminated inner margins and obliquely placed (Pl. XXVI, Fig. 1*f*). The interambulacral areas are formed of broad plates that bear numerous small perforated and mammillated tubercles. A microscopic granulation covers the miliary space (Pl. XXVI, Fig. 1*e*).

The apical disk is small and compact and the perforations of the genital plates distinct (Pl. XXVI, Fig. 1*g*).

The mouth opening is large, excentric, situated at some distance in front of the center of the base. The anal opening is large, acuminated on the upper margin, and placed in a broad, deep anal sulcus that extends from near the apical disk to the posterior margin (Pl. XXVI, Fig. 1*d*).

Related forms.—*Echinobrissus expansus* has no points that would closely ally it with any species of this genus hitherto described.

Locality and geological horizon.—This species is from the Ripley group (upper Cretaceous) of Alabama or Mississippi, but its exact locality is not recorded.

Collection.—Philadelphia Academy of Natural Sciences.

ECHINOBRISSUS TEXANUS Clark.

Plate XXVI, Figs. 2*a–f*.

Echinobrissus texanus Clark, 1891. Johns Hopkins University Circulars, No. 87, p. 76.

Determinative characters.—Test ovate, rounded anteriorly, subquadrate posteriorly; upper surface convex, apex forward of the center; base concave. Ambulacra lanceolate, subpetaloidal. Apical disk forward of the center. Mouth opening small, excentric. Anal opening small, oval, in narrow sulcus that begins some distance below the apical disk.

Dimensions.—Length, ¾ inch; width, ⅝ inch; height, $\frac{5}{16}$ inch.

Description.—The single specimen of this species is somewhat damaged on the sides, so that the ambital outline is not complete. It is ovate in form, broader posteriorly, and subquadrate. The upper surface is convex, but more or less compressed. The lower surface is concave.

The ambulacral areas are narrowly lanceolate. The poriferous zones for a short distance from the apical disk are subpetaloid in form. The posterior ambulacra are much longer than the others, the unpaired ambulacrum being the shortest. The pores of each plate are oval and set at an angle to one another (Pl. XXVI, Fig. 2*e*).

The interambulacral plates are large and covered with irregularly arranged tubercles. Between the tubercles a microscopic granulation covers the surface (Pl. XXVI, Fig. 2*f*).

The apical disk is small and situated forward of the apex. The individual plates can not be fully distinguished on the specimen examined. The mouth opening is apparently small, though somewhat obscured. It is situated forward of the center of the base.

The anal opening is small, placed in a narrow sulcus that begins some distance posterior to the apical disk.

Related forms.—*Echinobrissus texanus* is readily separated from *E. expansus* by its ovate form and the shape and size of the anal sulcus. It is unlike any European species.

Locality and geological horizon.—This form is from the Austin chalk (upper Cretaceous) of the south bank of the Colorado river, Austin, Texas.

Collection.—U. S. National Museum.

TREMATOPYGUS d'Orbigny.

TREMATOPYGUS CRUCIFER (Morton).

Plate XXVII, Figs. 1*a–i*.

Ananchytes cruciferus Morton, 1830. Am. Jour. Sci., 1st ser., vol. 18, p. 245, Pl. 3, Fig. 8.

Ananchytes cruciferus Morton, 1830. Philadelphia Acad. Nat. Sci., 1st ser., vol. 6, pp. 201, 202.

Nucleolites crucifer Morton, 1833. Am. Jour. Sci., 1st ser., vol. 23, p. 294.

Nucleolites crucifer Morton, 1834. Synop. Organ. Remains, Cretaceous, p. 75, Pl. 3, Fig. 15.

Nucleolites cruciferus Agassiz, 1840. Cat. Syst., p. 4.

Nucleolites cruciferus d'Orbigny, 1847. Prodrome, vol. 2, p. 271, Étage 22, No. 1197.

Nucleolites cruciferus Agassiz and Desor, 1847. Cat. rais., p. 97.

Nucleolites crucifer Bronn, 1848. Index Pal., vol. 1, p. 818.

Pygorhynchus crucifer Ravenel, 1850. Am. Assoc. Adv. Sci. Proc., p. 160.

Trematopygus crucifer d'Orbigny, 1853–'60. Paléont. française, vol. 6, p. 387, Pl. 953, Figs. 10, 11; Pl. 963, Figs. 1–5.

Echinobrissus cruciferus d'Orbigny, 1854. Revue zool., p. 25.

Nucleolites crucifer Desor, 1858. Synop. des Échinides fossiles, p. 262.

Nucleolites crucifer Gabb, 1859. Cat. Invert. Fossils Cretaceous, p. 19.

Nucleolites crucifer Meek, 1864. Smith Misc. Coll., vol. 7 (177), p. 2.

Nucleolites crucifer Cook, 1868. Geol. of New Jersey, p. 377.

Nucleolites crucifer Conrad, 1868. Geol. of New Jersey, App., p. 722.

Nucleolites cruciferus Credner, 1870. Zeitschr. d. deutsch. geol. Gesells., XXII, p. 217.

Trematopygus crucifer Clark, 1891. Johns Hopkins University Circulars, No. 87, p. 76.

Determinative characters.—Test ovate, inflated at the sides and base and slightly contracted anteriorly. Ambulacra long, well defined; pores unigeminal, prominent on the upper surface, indistinct on the base. Apical disk situated anteriorly. Mouth opening large and oblique. Anal opening large, oval, supramarginal.

Dimensions.—Length, 1 inch; breadth, $\frac{7}{8}$ inch; height, $\frac{3}{4}$ inch.

Description.—This urchin is not uncommon at Timber creek, New Jersey, where many very perfect specimens have been obtained. Its

outline is ovate and very regular, lacking at the ambitus or apex any sharply defined angularity. The sides are highly inflated, together with the outer portion of the base.

The ambulacral areas are long, lanceolate, and unequal; the posterior pair are the longest, the unpaired anterior area is the shortest. The areas do not produce any irregularity in the outline of the test beyond inconsiderable depressions in the immediate vicinity of the mouth edges. The poriferous zones are clearly marked on the upper surface, and the pore pairs are nearly horizontal (Pl. XXVII, Fig. 1*f*), but toward the ambitus the pores become smaller, those of each pair nearer together, and the pairs obliquely situated at the lower, outer corner of each plate (Pl. XXVII, Fig. 1*e*); near the mouth edges they again become larger and slightly increased in number.

The interambulacral areas are wide and composed of large plates that are bent in the middle. The surface is covered with irregular rows of tubercles that are perforated and mammillated. The miliary space in its turn is covered with numerous minute and irregularly distributed granules.

The apical disk is small and anteriorly situated; the four genital plates are distinctly perforated, those of the anterior pair situated much nearer together than those of the posterior (Pl. XXVII, Fig. 1*g*).

The mouth opening is large, oblique, and placed somewhat forward of the center of the base. The anal opening is large, oval, and acuminate at the upper extremity. It is situated in an anal sulcus, that makes a marked indentation in the posterior margin, and is bordered by two well defined ridges (Pl. XXVII, Fig. 1*d*).

Related forms.—*Trematopygus crucifer* (Morton) is a unique species that affords no closely allied forms in either American or European deposits. It is the single representative of this genus recorded from American strata.

Locality and geological horizon.—The only specimens of this form thus far reported are from the yellow limestone of the middle marl bed (upper Cretaceous) of Timber creek, New Jersey.

Collections.—American Museum of Natural History, New York; Philadelphia Academy of Natural Sciences; Johns Hopkins University.

CATOPYGUS Agassiz.

CATOPYGUS OVIFORMIS Conrad.

Plate XXVII, Figs. 2*a–f*.

Catopygus oviformis Conrad, 1847. Philadelphia Acad. Nat. Sci. Jour., 2d ser., vol. 2, p. 39, Pl. 1, Fig. 9.

Nucleolites oviformis (Catopygus) Conrad, 1868. Geol. of New Jersey, App., p. 722.

Catopygus oviformis Clark, 1891. Johns Hopkins University Circulars, No. 87, p. 76.

Determinative characters.—Test ovate, broader posteriorly; upper surface nearly flat; apex posterior to apical disk. Ambulacra narrow, subpetaloidal. Interambulacra wide; single interambulacrum elevated.

Apical disk excentric, nearer the anterior border. Mouth opening small, excentric, nearer the anterior margin. Anal opening oval, situated in a narrow sulcus, that terminates above in a projecting arch.

Dimensions.—Length, $\frac{7}{8}$ inch; width, $\frac{3}{4}$ inch; height, $\frac{7}{16}$ inch.

Description.—The test of this very beautiful little form is ovate, with rounded, inflated sides and elevated upper surface. The base is nearly flat, slightly concave in the vicinity of the mouth edges, and lobed posteriorly.

The ambulacral areas are narrowly lanceolate, subpetaloidal on the upper surface, the two posterior areas being much longer than the others. The plates in the petaloidal portions are narrow, but beyond increase in breadth (Pl. XXVII, Fig. 2*e*).

The large interambulacral plates are covered with minute tubercles, between which are numerous microscopic granules.

The apical disk is small, excentric, and situated far anterior to the apex (Pl. XVII, Figs. 2*a*, 2*c*).

The mouth opening is small and situated nearer the anterior margin.

The anal opening is oval and placed at the upper part of a nearly vertical anal sulcus. The upper margin of this sulcus forms a beak-shaped prominence that overhangs the opening (Pl. XXVII, Fig. 2*d*).

Related forms.—It is separated from *C. pusillus* Clark, the other American species, by its narrower outline, more inflated sides, and the anterior position of its apical disk. In form it is somewhat like *C. columbarius*, which is widely distributed in the Cenomanian of Europe, but the position of the apical disk at once distinguishes it.

Locality and geological horizon.—This species is from the yellow limestone of the middle marl bed (upper Cretaceous) of Timber creek, New Jersey.

Collection.—Philadelphia Academy of Natural Sciences.

CATOPYGUS PUSILLUS Clark.

Plate XXVII, Figs. 3*a–d*.

Catopygus pusillus Clark, 1891. Johns Hopkins University Circulars, No. 87, p. 76.

Determinative characters.—Test ovate to subquadrate, rounded anteriorly, subquadrate posteriorly, broader behind than before; upper surface elevated; base concave. Ambulacra narrowly lanceolate, subpetaloidal on the upper surface. Apical disk small, nearly central. Mouth opening small, anteriorly placed. Anal opening oval, in vertical sulcus beneath overhanging arch.

Dimensions.—Length, $\frac{5}{8}$ inch; width, $\frac{2}{16}$ inch; height, $\frac{3}{8}$ inch.

Description.—All the specimens of this species examined by the writer are casts, that are, however, sufficiently well preserved to admit of the determination of all the more important characters. The test is ovate to subquadrate, occasioned by the slight angularity of the posterior margin. The anterior portion is regularly rounded.

The ambulacral areas are narrow, the posterior pair only slightly longer than the anterior.

The interambulacral areas are wide and composed of large plates.

The apical disk is small and situated nearly in the center of the upper surface.

The mouth opening is small and placed forward of the center of the base. The anal opening is situated in a nearly vertical sulcus that is overhung at its upper extremity by a projecting arch (Pl. XXVII, Fig. 3*c*).

Related forms.—*Catopygus pusillus* is separated from *C. oviformis* by its broader and slightly subquadrate form, less rounded sides, and nearly central position of the apical disk.

Locality and geological horizon.—*Catopygus pusillus* is from the lower marl bed (upper Cretaceous) of Wordills, Monmouth county, New Jersey.

Collection.—U. S. National Museum.

CASSIDULUS Lamarck.

CASSIDULUS FLOREALIS (Morton).

Plate XXVIII, Fig. 1*a–l*.

Clypeaster sp. Morton, 1830. Philadelphia Acad. Nat. Sci. Jour., 1st ser., vol. 6, p. 202.
Clypeaster florealis Morton, 1833. Amer. Jour. Sci., 1st ser., vol. 23, p. 294.
Clypeaster florealis Morton, 1834. Synop. Organ. Remains Cretaceous, p. 76, Pl. 3, Fig. 12, and Pl. 10, Fig. 12.
Pygurus florealis Agassiz and Desor, 1847. Cat rais., p. 141.
Clypeaster florealis Bronn, 1848. Index Pal., p. 312.
Faujasia florealis d'Orbigny, 1853–'60. Paléont. française, vol. 6, p. 319, Pl. 920, Figs. 5, 6.
Faujasia florealis Desor, 1858. Synop. des Échinides fossiles, p. 318.
Clypeaster florealis Gabb, 1859. Synop. Invert. Fossils, Cretaceous, p. 18.
Cassidulus florealis Meek, 1864. Smith Misc. Coll., vol. 7 (177), p. 2.
Pygurus florealis Conrad, 1868. Geol. of New Jersey, App., p. 722.
Cassidulus florealis Clark, 1891. Johns Hopkins University Circulars, No. 87, p. 76.

Determinative characters.—Test subconoidal in outline, subpentagonal, slightly longer in the antero-posterior diameter than the lateral, rounded anteriorly, angular posteriorly; apex slightly forward of the center. Ambulacra narrow; poriferous zones petaloidal on the upper two-thirds of the dorsal surface. Interambulacra wide, covered with small perforated tubercles. Apical disk small, situated anteriorly. Mouth opening pentagonal, with well-developed floscelle. Anal opening supramarginal, in short, narrow sulcus.

Dimensions.—Length, $1\frac{3}{8}$ inches; breadth, $1\frac{1}{4}$ inches; height, $\frac{3}{4}$ inch.

Description.—This species, the earliest of this genus recognized from American deposits, has a subconoidal test of moderate height, with a subpentagonal margin. The angularity is more pronounced posteriorly than anteriorly, the anterior portion of the margin being distinctly rounded. The antero-posterior diameter is but slightly greater

than the lateral, while the height is a little more than one half of the same. The apex is a short distance in front of the center of the upper surface, the slope of the anterior face being sharper than the posterior (Pl. XXVIII, Fig. 1*c*).

The ambulacral areas are narrow. The poriferous zones consist of a double row of pores that are arranged in petaloidal form on the upper two-thirds of the dorsal surface, and as phylloidal expansions in the vicinity of the mouth edges (Pl. XXVIII, Fig. 1*c*). In the petaloidal portion the pores of the inner row are oval, those of the outer elongated, and each pair united by a shallow furrow (Pl. XXVIII, Fig. 1*f*). Toward the margin the pores are smaller and placed near together (Pl. XXVIII, Fig. 1*g*), and so continue until near the peristome, when the poriferous zones suddenly expand. At this point the pores increase in size and distance from one another. Between the oral lobes the poriferous zones again suddenly contract.

The interambulacral areas are of unequal width; the anterior pair are the narrowest; the three posterior are of about equal width and nearly one-half wider than the anterior. The surface of the plates is irregularly covered with numerous small perforated tubercles with sunken areolas, between which are numerous microscopic granules (Pl. XXVIII, Fig, 1*i*).

The apical disk is composed of four perforated genital and five small ocular plates. The fifth genital is apparently obsolete, as it could not be observed on any of the several very perfect specimens examined. The large right antero-lateral genital plate, the madreporite, extends across the disk, forming a large portion of the center of that body (Pl. XXVIII, Fig. 1*j*).

The mouth opening is large, pentagonal, and slightly nearer the anterior margin. It is surrounded by five prominent lobes, that project over the oral opening. Between the lobes the ambulacra are contracted and beyond the same expand to form wide phylloidal areas. The peculiar, somewhat star-shaped, form thus produced has been termed *floscelle* by Desor (Pl. XXVIII, Fig. 1*b*).

The anal opening is small, circular, and supra-marginal, and is situated in a short, narrow sulcus (Pl. XXVIII, Figs. 1*a*–1*d*).

Related forms.—*Cassidulus florealis* is allied to *C. æquoreus*, though the latter is more depressed and more elongated. *C. subconicus* presents some points of similarity, but has a more sharply defined pentagonal outline, a differently situated anal opening, and more elongated pores in the outer rows of the petaloidal areas.

Locality and geological horizon.—This species is reported from the lower marl bed (upper Cretaceous) of New Jersey and Delaware.

Collection.—Philadelphia Academy of Natural Sciences.

CASSIDULUS ÆQUOREUS Morton.

Plate XXIX, Figs. 1*a–i*.

Cassidulus æquoreus Morton, 1834. Synop. Organ. Remains, Cretaceous, p. 76, Pl. 3, Fig. 14.
Cassidulus æquoreus Desmoulins, 1837. Études sur les Échinides, p. 146.
Cassidulus æquoreus Agassiz and Desor, 1847. Cat. rais., p. 141.
Cassidulus æquoreus d'Orbigny, 1847. Prodrome, vol. 2, p. 271.
Cassidulus æquoreus Bronn, 1848. Index Pal., vol. 1, p. 244.
Cassidulus æquoreus d'Orbigny, 1853–'60. Paléont. française, vol. 6, p. 329, Pl. 926, Fig. 6–12.
Cassidulus æquoreus Desor, 1858. Synop. des Échinides fossiles, p. 290.
Cassidulus æquorum Gabb, 1859. Cat. Invert. Fossils, Cretaceous, p. 18.
Cassidulus æquoreus Meek, 1864. Smith Misc. Coll., vol. 7 (177), p. 2.
Cassidulus æquoreus Conrad, 1868. Geol. of New Jersey, App., p. 722.
Cassidulus æquoreus Clark, 1891. Johns Hopkins University Circulars, No. 87, p. 76.

Determinative characters.—Test subpentagonal, depressed; upper surface convex; under surface concave, slightly rostrated posteriorly; apex forward of the center. Ambulacra narrow; poriferous zones petaloidal on the upper surface; contracted above the margin and expanded again on the lower surface, much narrowed at the peristome. Interambulacra wide, covered with small perforated tubercles. Apical disk small, situated forward of the center. Mouth opening small, with floscelle. Anal opening supramarginal, in short sulcus.

Dimensions.—Length, 1¼ inches; width, 1⅛ inches; height, ⅝ inch.

Description.—This typical Cassidulus, early recognized as such by Dr. Morton, has a depressed test, subpentagonal in outline. It is longer in the antero-posterior diameter than the lateral. The upper surface is convex, with sharp marginal edges, while the lower surface is flat, with a slight concavity toward the center. The apex is somewhat anterior to the center.

The ambulacral areas are narrow. The poriferous zones are unigeminal, the pores of the upper part of the dorsal surface arranged in petaloidal form. At a point varying in the different areas from one-quarter to one-third of the distance from the margin to the apical disk, the zones are contracted and continue as narrow bands over the margin and to the vicinity of the peristome, where they broaden again perceptibly, becoming finally much contracted at the margin of the oral opening (Pl. XXIX, Fig. 1*e*). The pores are distinct in the petaloidal portion (Pl. XXIX, Fig. 1*f*) and in the broadened area near the peristome (Pl. XXIX, Fig. 1*g*), but in the intermediate contracted portion are small and indistinct. The interambulacral areas are broad, and covered by small perforated tubercles with sunken areolas.

The apical disk is composed of four perforated genital and five small ocular plates. As explained under the previous species, the fifth genital is obsolete (Pl. XXIX, Fig. 1*h*).

The mouth opening is pentagonal and surrounded by a well-developed

floscelle. The oral lobes are very prominent and the ambulacral furrows much contracted (Pl. XXIX, Fig. 1*i*).

The anal opening is situated in a short sulcus on the upper surface (Pl. XXIX, Figs. 1*a*–1*d*).

Related forms.—This species is separated from the preceding, with which it has much in common, by its more depressed and elongated form. From *C. micrococcus* it is separated by its sharper apex, more angular margin, the position of the anal opening, and the shorter pore openings in the outer rows.

Locality and geological horizon.—This species is reported from the Ripley group (upper Cretaceous) of Alabama. No more definite statement as to the locality is given.

Collection.—Philadelphia Academy of Natural Sciences.

CASSIDULUS MICROCOCCUS Gabb.

Plate XXX, Figs. 1*a*–*i*.

Cassidulus micrococcus Gabb, 1860. Philadelphia Acad. Nat. Sci. Proc., p. 519.
Cassidulus micrococcus Clark, 1891. Johns Hopkins University Circulars, No. 87, p. 76.

Determinative characters.—Test oval, rounded anteriorly, slightly rostrated posteriorly; upper surface convex, flattened at the apex; sides equally declining. Ambulacra moderately broad; poriferous cones petaloidal on dorsal surface; outer row of pores slit-like in petaloidal portion. Mouth opening small, pentagonal, with floscelle. Anal opening oval, situated high on upper surface, in long, narrow sulcus.

Dimensions.—Length, 1¾ inches; width, 1½ inches; height, ¾ inch.

Description.—This species has a distinctly oval form, wider posteriorly. The upper surface is elevated at the margin, but somewhat flattened at the apex. The sides decline very nearly equally. The base is flattened, with a slight concavity at the mouth edges. The posterior margin is truncated and slightly rostrated.

The ambulacral areas are rather broad, contracted about one-quarter of the distance from the ambitus to the apex, and narrowed nearly to the peristome, where they are again broadened to form indistinct phylloidal areas (Pl. XXX, Figs. 1*f*, 1*g*). The pores are slit-like in the outer rows of the petaloidal portion (Pl. XXX, Fig. 1*f*).

The interambulacral plates are covered with minute tubercles, with sunken areolas, that increase in size and number on the base (Pl. XXX, Fig. 1*i*).

The apical disk is situated slightly in front of the center of the upper surface. The right anterior genital plate, which is modified to form the madreporite, is very large. The posterior genital is not developed, or if present the suture is obscured (Pl. XXX, Fig. 1*h*).

The anal opening is oval, situated high upon the upper surface, in a long, narrow, and deep sulcus (Pl. XXX, Figs. 1*a*, 1*d*).

Related forms.—A comparison of this species with *Cassidulus æquo-*

reus, as made also by Gabb in his original description, shows that the present form is much larger and more oval, and that the anal opening is situated higher and in a deeper and longer sulcus, and, furthermore, that the pores of the outer row in the petaloidal portion are elongated and slit-like.

Locality and geological horizon.—This species is from the Ripley group (upper Cretaceous) of Eufaula, Alabama.

Collection.—Philadelphia Academy of Natural Sciences.

CASSIDULUS SUBQUADRATUS Conrad.

Plate XXXI, Figs. 1 *a–h*.

Cassidulus subquadratus Conrad, 1860. Philadelphia Acad. Nat. Sci. Jour., 2d ser., vol. 4, p. 291, Pl. 47, Fig. 19.

Cassidulus subquadratus Clark, 1891. Johns Hopkins University Circulars, No. 87, p. 76.

Determinative characters.—Test subquadrate to subpentagonal, hemispherical; sides equally declining, upper surface convex; lower surface concave; posterior margin truncated and rostrated. Poriferous zones broadly petaloidal on upper two-thirds of the dorsal surface; sharply contracted at lower margin of petaloidal areas. Mouth opening small, pentagonal, with well-defined floscelle. Apical disk large, slightly anterior to the center. Anal opening round, in deep sulcus.

Dimensions.—Length, 2¼ inches; width, 2 inches; height, 1 inch.

Description.—This remarkably symmetrical *Cassidulus* has a nearly hemispherical form. In outline it is nearer subpentagonal than subquadrate, due to the rostrated character of the posterior margin, which is at the same time truncated. The anterior margin is rounded. The lateral edges are nearly parallel, though somewhat more approximated anteriorly. The apex is slightly forward of the center.

The ambulacral areas are moderately wide in the petaloidal portion, narrow beyond. The poriferous zones are composed in the petaloidal portion of an inner row of small, nearly circular pores and of an outer row of oblique slit-like openings. The pores of each pair are united by a shallow furrow (Pl. XXXI, Fig. 1*f*). Beyond the petaloidal areas the narrow plates of those portions give place to broad plates, each with a pair of small, round pores in the lower and outer corner (Pl. XXXI, Fig. 1*c*). In the vicinity of the peristome the poriferous zones expand and the pores increase in size, though apparently reduced in number (Pl. XXXI, Fig. 1*g*). The last pair of plates are much contracted.

The interambulacral areas are wide. The plates are covered with minute tubercles with depressed areolas, which become larger and more prominent on the lower surface.

The apical disk is large, composed of four perforated genital and five ocular plates. The fifth genital is apparently obsolete (Pl. XXXI, Fig. 1*h*).

The mouth opening is small, pentagonal, and surrounded by a well-developed floscelle. The anal opening is round and situated high above the margin, in a deep sulcus, that becomes narrower and shallower toward the ambitus.

Related forms.—This species is most closely related to *Cassidulus subconicus*, but the latter is much more elevated, while the anal opening is situated higher and in a less depressed sulcus than in *C. subquadratus*.

Locality and geological horizon.—This form is from the Ripley formation (upper Cretaceous) of Mississippi. The specimen described is from Holly Springs, and was collected by Mr. W. J. McGee.

Collection.—U. S. National Museum.

Cassidulus subconicus Clark.

Plate xxxii, Figs. 1*a–k*.

Cassidulus subconicus Clark, 1891. Johns Hopkins University Circulars, No. 87, p. 76.

Determinative characters.—Test subconical; margin subpentagonal, truncated and rostrated posteriorly; apex anteriorly placed. Ambulacra broad in petaloidal portion, narrow beyond; poriferous zones unigeminal, pores with slit-like openings in outer row of petaloidal areas. Apical disk large, anteriorly situated. Mouth opening subcircular, with very prominent floscelle. Anal opening large, situated high on upper surface in shallow sulcus.

Dimensions.—Length, $1\frac{7}{8}$ inches; width, $1\frac{3}{4}$ inches; height, $1\frac{1}{8}$ inches.

Description.—The outline of this form is so similar to the one preceding that there was some hesitation, at first, in establishing it as an independent species. More careful examination of numerous specimens of each species has proved the constant occurrence of the individual differences. *Cassidulus subconicus* is, as its name signifies, subconical. In marginal outline it is subpentagonal, the posterior border more or less rostrated and clearly truncated. The apex is slightly forward of the center, giving a somewhat sharper slope to the anterior portion of the test than to the posterior.

The ambulacral areas are broad in the petaloidal portion, beyond which they are narrowed. At the margin they again acquire considerable width, but gradually contract beyond, although expanded for a short distance in the phylloidal area near the mouth opening (Pl. xxxii, Fig. 1*e*). At the peristome the final pair of plates is highly attenuated (Pl. xxxii, Fig. 1*g*). The pores of the outer rows, in both the petaloidal and phylloidal areas, are in a marked degree elongated. In the intermediate portion of the column they are small and indistinct.

The interambulacral areas are more prominent than the ambulacral, which are slightly depressed. The surface is covered with minute tubercles and a microscopic granulation (Pl. xxxii, Fig. 1*i*).

The apical disk is large, and composed of four perforated genital

plates and five ocular plates. The fifth genital is apparently obsolete (Pl. XXXII, Fig. 1*k*).

The mouth opening is large, subcircular, and surrounded by a very prominent floscelle (Pl. XXXII, Fig. 1*h*). The anal opening is large, circular, and is situated high above the margin in a shallow sulcus.

Related forms.—*Cassidulus subconicus* is closely related to *C. subquadratus*, but is separated from it by its high subconical test, more elevated anal opening, and shallow anal sulcus.

Locality and geological horizon.—Like the preceding species, *Cassidulus subconicus* is from the Ripley group (upper Cretaceous) of Mississippi.

Collection.—U. S. National Museum.

CASSIDULUS PORRECTUS Clark.

Plate XXXIII, Figs. 1*a–b*; Plate XXXIV, Figs. 1*a–b*; Plate XXXV, Figs. 1*a–d*.

Cassidulus porrectus Clark, 1891. Johns Hopkins University Circulars, No. 87, p. 76.

Determinative characters.—Test very large, subcircular, oval, depressed; upper surface convex; lower surface concave; broader posteriorly than anteriorly; apex forward of the center. Ambulacra broad. Interambulacra thickly covered with minute tubercles. Apical disk small, forward of the center. Mouth opening large, subconical, with prominent floscelle. Anal opening supra-marginal, in short shallow sulcus.

Dimensions.—Length, 4 inches; width, 4 inches; height, 2 inches.

Description.—This very large Cassidulus, with one exception the largest Echinoid in the American Mesozoic, has an irregularly oval, depressed test, that is subcircular in marginal outline. The breadth is equal to the length, but is greatest in the posterior portion, so that the margin appears contracted anteriorly. The apex is some distance forward of the center and slightly flattened. The posterior margin is feebly truncated.

The ambulacral areas are wide; the contractions below the petaloidal region and above the phylloidal continue for short distances, while the lowest pair of plates in the column bordering the mouth opening are long and greatly attenuated (Pl. XXXV, Fig. 1*a*). The pores of the outer rows are slit-like in form and obliquely placed (Pl. XXXV, Figs. 1*b*, 1*c*).

The interambulacral areas are prominent; the plates are covered with numerous small tubercles, with depressed areolas, which are larger and more prominent on the under than the upper surface (Pl. XXXIII. Fig. 1*d*). The apical disk is small and is placed forward of the center.

The mouth opening is large, subcircular, with very prominent floscelle. The oral lobes project far beyond the level of the base and are separated by deep ambulacral furrows (Pl. XXXIV, Fig. 1*a*).

The anal opening is large, oval, and is situated at the head of a short, narrow sulcus (Pl. XXXIII, Figs. 1*a*, 1*b*).

Related forms.—*Cassidulus porrectus* is from its size, form, and details of structure readily separated from the other species of Cassidulus described from the American and European Mesozoic.

Locality and geological horizon.—*Cassidulus porrectus* is from the Ripley group (upper Cretaceous), of Eufaula, Alabama. In the preliminary report, published in the Johns Hopkins Circulars, the writer incorrectly cites Mississippi as the locality.

Collection.—U. S. National Museum.

CASSIDULUS STANTONI Clark.

Plate XXXV, Figs. 2*a*–*d*.

Cassidulus Stantoni Clark, 1891. Johns Hopkins University Circulars, No. 87, p. 76.

Determinative characters.—Test small, subovate, elevated; upper surface convex, lower surface concave; apex forward of the center. Ambulacra very narrow. Apical disk small, forward of the center. Mouth opening small, with floscelle. Anal opening high above margin, in long, narrow, and deep sulcus.

Dimensions.—Length, $\frac{5}{8}$ inch; width, $\frac{1}{2}$ inch; height, $\frac{1}{4}$ inch.

Description.—This minute Cassidulus has a subovate test, an elevated, convex upper surface and a concave lower surface. It is broader posteriorly than anteriorly, and the posterior margin is truncated. The apex is situated slightly anterior to the center of the upper surface (Pl. XXXV, Fig. 2*a*).

The ambulacral areas are very narrow. The petaloidal portion but slightly exceeds the remainder in width, which is nearly equal throughout. The phylloidal region is feebly outlined.

The interambulacral areas are broad, but the poor state of preservation of the specimens renders it impossible to determine all the details of structure.

The apical disk is small and forward of the center, but not sufficiently well preserved to distinguish the individual plates. The mouth opening is small and surrounded by a feeble floscelle. The anal opening is round and situated high above the margin, at the head of a narrow, deep sulcus (Pl. XXXV, Figs. 2*a*, 2*d*).

Related forms.—*Cassidulus Stantoni* is quite unlike any other representative of this genus from American strata, and can not be readily associated with any European species.

Locality and geological horizon.—This species is from the Colorado group (upper Cretaceous) of Muddy creek, Huerfano county, Colorado.

Collection.—U. S. National Museum.

HOLASTERIDÆ.

Test ovate or cordate. Ambulacra narrow; poriferous zones narrow, pores unigeminal. Apical disk elongated, at times so much that the three anterior ambulacra are widely separated from the two posterior. Mouth opening excentric, anteriorly situated. Anal opening inframarginal or marginal.

ANANCHYTES Mercati.

ANANCHYTES OVALIS Clark.

Plate XXXVI, Fig. 1*a–h*.

Determinative characters.—Test subovate cordate; contracted posteriorly; upper surface convex; lower surface flat. Apical disk elongated, consisting of four perforated genital and five ocular plates situated slightly forward of the center. Mouth opening near the anterior margin. Anal opening oval, situated on a slight protuberance of the posterior margin.

Dimensions.—Length, 1¾ inches; width, 1½ inches; height, 1¼ inches.

Description.—The two specimens of this species collected by the writer are remarkably well preserved and admit of the determination of all the essential features. The test is in lateral outline subovate, though somewhat cordate in form when viewed from above or below. A marked protuberance (Pl. XXXVI, Fig. 1*c*) is present on the posterior margin that appears as a slight ridge on the lower surface between the mouth and anal openings. The upper surface is convex. The sides are full and rounded at the ambitus. The base is nearly flat, with the exception of the slight ridge and depressed mouth edges.

The ambulacral areas are wide and straight, attaining their greatest width just above the ambitus. The pores are oval, and those of each pair are placed at an angle to one another (Pl. XXXVI, Fig. 1*g*). The surface of both the ambulacral and interambulacral plates is covered by small tubercles, between which are numerous microscopic granules. The apical disk is elongated (Pl. XXXVI, Fig. 1*f*). The four genital plates are large and distinctly perforated. The anterior, right-hand genital plate, which serves as the madreporite, is much larger than any of the others, being several times the size of the anterior left-hand genital, with which it is in contact. The posterior genitals are very nearly of equal size.

The mouth opening is transversely oblong and situated near the anterior margin. The anal opening is oval and situated on a marked protuberance on the posterior margin.

Related forms.—The present species is the only representative of the genus recognized from American deposits. It is more ovate and less elevated than the forms described from European strata.

Locality and geological horizon.—This species is from the yellow limestone of the middle marl bed (upper Cretaceous) of Vincentown, New Jersey.

Collection.—Johns Hopkins University.

CARDIASTER Forbes.

CARDIASTER CINCTUS Morton.

Plate XXXVII, Figs. 1*a–h*.

Spatangus sp. Morton, 1829. Philadelphia Acad. Nat. Sci. Jour., 1st ser., vol. 6, p. 122.
Ananchytes sp. Morton, 1830. Am. Jour. Sci., 1st ser., vol. 17, p. 287.
Ananchytes cinctus Morton, 1830. Philadelphia Acad. Nat. Sci. Jour., 1st ser., vol. 6, p. 200.
Ananchytes fimbriatus Morton, 1830. Philadelphia Acad. Nat. Sci. Jour., 1st ser., vol. 6, p. 200.
Ananchytes cinctus Morton, 1830. Am. Jour. Sci., 1st ser., vol. 18, p. 246, Pl. 3, Fig. 7.
Ananchytes fimbriatus Morton, 1830. Am. Jour. Sci., 1st ser., vol. 18, p. 245, Pl. 3, Fig. 9.
Ananchytes cinctus Morton, 1834. Synop. Organ. Remains, Cretaceous, p. 78, Pl. 3, Fig. 19.
Ananchytes fimbriatus Morton, 1834. Synop. Organ. Remains, Cretaceous, pp. 77, 79, Pl. 3, Fig. 20.
Holaster cinctus Agassiz and Desor, 1840. Cat. Syst., p. 1.
Holaster cinctus Agassiz and Desor, 1847. Cat. rais., p. 133.
Holaster fimbriatus Agassiz, 1847. Cat. rais., p. 141.
Holaster cinctus d'Orbigny, 1847. Prodrome, vol. 2, p. 269.
Holaster fimbriatus d'Orbigny, 1847. Prodrome, vol. 2, p. 269.
Holaster cinctus Bronn, 1848. Index Pal., vol. 1, p. 593.
Ananchytes fimbriatus Bronn, 1848. Index Pal., vol. 1, p. 70.
Cardiaster cinctus d'Orbigny, 1853–'60. Paléont. française, vol. 6, p. 147; Pl. 905, Fig. 4.
Cardiaster fimbriatus d'Orbigny, 1853–'60. Paléont. française, vol. 6, p. 147; Pl. 905, Fig. 3.
Cardiaster cinctus (*Cardiaster fimbriatus*) Desor, 1858. Synop. des Échinides fossiles, p. 346.
Ananchytes cinctus Gabb, 1859. Cat. Invert. Fossils, Cretaceous, p. 18.
Ananchytes fimbriatus Gabb, 1859. Cat. Invert. Fossils, Cretaceous, p. 18.
Holaster cinctus Credner, 1870. Zeitschr. d. deutsch. geol. Gesells. XXII, p. 218.
Holaster cinctus Clark, 1891. Johns Hopkins University Circulars, No. 87, p. 77.

Determinative characters.—Test cordate, distinctly grooved anteriorly; contracted posteriorly; upper surface convex; lower surface flat. Ambulacra wide. Apical disk much elongated, consisting of four perforated genital and five ocular plates situated slightly forward of the center. Mouth opening near the anterior margin. Anal opening oval, situated on the truncated posterior margin.

Dimensions.—Length, 2 inches; width, 2 inches; height, 1¼ inches.

Description.—This species, which is among the earliest of the Echinoid forms recognized from American Cretaceous strata, is distinctly cordiform, with a pronounced groove on the anterior face that is occupied by the unpaired ambulacrum. Opposite thereto is a slight ridge at the central suture of the unpaired posterior interambulacrum that is sud-

denly terminated by the nearly vertically truncated surface of the posterior margin. The sides decline equally to the ambitus, giving an oval outline to the vertical lateral section. The lower surface is nearly flat, with the exception of the slight depressions directly at the mouth edges and the elevated area extending from the center of the base to the posterior margin.

The ambulacral areas are wide, apetaloid, and separated at the apex. The antero-lateral pair are bent backward in their upper part, beyond which they extend straight to the margin. The postero-lateral pair are bent somewhat forward, after which they extend straight over the margin. The single ambulacrum is situated in the deep anterior sulcus. The pores of the paired ambulacra consist, in the upper portion of the columns, of oblique oval openings united by furrows (Pl. XXXVII, Fig. 1*f*), while lower down they become small and often indistinct (Pl. XXXVII, Fig. 1*f*). In the unpaired ambulacrum the pores are extremely small.

The surface of the interambulacral as well as of the ambulacral plates is covered with fine granules, among which are irregularly scattered numerous small perforated tubercles.

The apical disk is narrow, elongated. The four perforated genital plates are disposed in pairs, between which two of the five ocular plates are situated. Forming the posterior portion of the disk are two more ocular plates, while the fifth plate comprises the anterior part. The ambulacral areas are on this account separated at their apices (Pl. XXXVII, Fig. 1*h*).

The mouth opening is transversely oblong and is situated near the anterior margin of the base. The anal opening is oval and situated on the truncated surface at the posterior margin of the test (Pl. XXXVII, Fig. 1*e*).

Related forms.—This species is separated from *Holaster simplex*, the only other closely related form found in American Mesozoic deposits, by its deep anterior sulcus and less inflated upper surface.

Locality and geological horizon.—*Cardiaster cinctus* is from the yellow limestone of the middle marl bed (upper Cretaceous) of Timber creek, New Jersey.

Collections.—Philadelphia Academy of Natural Sciences; American Museum of Natural History, New York.

HOLASTER Agassiz.

HOLASTER SIMPLEX Shumard.

Plates XXXVIII, Figs. 1*a–g;* XXXIX, Figs. 1*a–d.*

Holaster simplex Shumard, 1853. Rept. Expl. Red River of Louisiana in 1852, p. 210, Pl. 3. Fig. 2.

Holaster comanchesi Marcou, 1858. Geol. of North America, p. 40, Pl. 3, Fig. 3.

Holaster simplex Desor, 1858. Synop. des Échinides fossiles, p. 450.

Holaster comanchesi Desor, 1858. Synop. des Échinides fossiles, p. 449.

Holaster simplex Gabb, 1859. Cat. Invert. Fossils, Cretaceous, p. 19.
Holaster comanchesi Gabb, 1859. Cat. Invert. Fossils, Cretaceous, p. 19.
Holaster simplex Meek, 1861. Smith. Misc. Coll., vol. 7, (177), p. 3.
Holaster comanchesi Meek, 1861. Smith. Misc. Coll., vol. 7 (177), p. 3.
Holaster simplex Clark, 1891. Johns Hopkins University Circulars, No. 87, p. 77.

Determinative characters.—Test oblong, cordiform; upper surface much elevated, rounded, and grooved on the anterior face; lower surface flat; apex nearly central. Ambulacra wide; pores unigeminal, with slit-like openings in upper portion of the column that become indistinct toward the margin and upon the base. Apical disk compact and not greatly elongated. Mouth opening transversely oval, situated near the anterior margin. Anal opening large, on truncated posterior margin.

Dimensions.—Length, 2¾ inches; width, 2¼ inches; height, 2 inches.

Description.—After the most careful examination of a large number of specimens the writer has been unable to find any constant characters that would warrant the separation of the forms described as *Holaster simplex* and *Holaster comanchesi*. They are accordingly included under the same species. The test is oblong, cordiform, much elevated, rounded above and flattened below. A shallow groove occupies the anterior face of the test, producing a feeble emargination of the anterior ambitus. A slight ridge extends along the line of the central suture of the single interambulacrum, which is suddenly terminated by the truncated face of the posterior margin.

The ambulacral areas are wide. The poriferous zones of the paired ambulacra are in the case of the posterior pair bent more or less forward in their upper portions, and in the case of the anterior slightly backward. The pores of the paired ambulacra have elongated openings in the upper portion (Pl. XXXVIII, Fig. 1*d*) and become very small and indistinct below (Pl. XXXVIII, Fig. 1*e*). The pores of the unpaired ambulacrum are exceedingly small.

The surface of both interambulacral and ambulacral plates are covered by small tubercles, between which are numerous microscopic granules (Pl. XXXIX, Figs. 1*c*, 1*d*).

The apical disk is compact and rather short. The four genital plates are large and broad. The two interposed oculars are large; the remaining three very small (Pl. XXXVIII, Fig. 1*f*).

The mouth opening is large, transversely oblong, and situated near the anterior margin (Pl. XXXVIII, Fig. 1*b*). The anal opening is oval, acuminate above, and situated on the truncated posterior border (Pl. XXXIX, Fig. 1*b*).

Related forms.—*Holaster simplex* is separated from *Cardiaster cinctus* by its more elevated upper surface and shallow anterior sulcus. It is very like *Holaster lævis*, var. *planus*, from the European Cretaceous, but is more elevated and distinctly broader posteriorly.

Locality and geological horizon.—This species is from the Washita formation of the Comanche series (lower Cretaceous) of Texas. It is

found in Bell and Bexar counties, and near Fort Worth; also at Preston, Grayson county, on the Red river and at Austin. It is also found near Fort Washita, Indian Territory.

Collection.—U. S. National Museum.

SPATANGIDÆ.

Test bilaterally symmetrical, generally cordiform. Ambulacra unequal and petaloidal. Apical disk compact. Mouth opening transversely bilabiate or pentagonal, situated anteriorly. Anal opening posteriorly situated and supra-marginal. Spines of different sizes.

ENALLASTER D'Orbigny.

Enallaster texanus (Roemer).

Plate XXXIX, Figs. 2*a–g*.

Toxaster texanus Roemer, 1849. Texas, etc., p. 393.
Toxaster texanus Roemer, 1852. Die Kreidebildungen von Texas, p. 85, Pl. 10, Fig. 3.
Toxaster ungula Giebel, 1853. Jahresber. des naturw. Vereins in Halle, p. 373.
Enallaster texasus d'Orbigny, 1853–'60. Paléont. française, vol. 6, p. 181, Pl. 850, Fig. 1–7.
Toxaster texanus Conrad, 1857. U. S. and Mex. Bound. Surv. Rept., vol. 1, pt. 2, p. 145, Pl. 1, Fig. 2*a–2c*.
Enallaster texanus Desor, 1858. Synop. des Échinides fossiles, p. 358.
Toxaster texanus Gabb, 1859. Cat. Invert. Fossils, Cretaceous, p. 19.
Toxaster texanus Meek, 1864. Smith. Misc. Coll., vol. 7 (177), p. 3.
Enallaster texanus Clark, 1891. Johns Hopkins University Circulars, No. 87, p. 77.

Determinative characters.—Test oblong, cordiform, broad in anterior portion, contracted and truncated posteriorly, with deep anterior groove; upper surface convex, elevated; base flat, depressed at the mouth opening; sides rounded; apex excentric and posterior. Ambulacra narrow and unequal, the postero-lateral pair much shorter than the others. Apical disk small and compact. Anal opening situated high above the margin.

Dimensions.—Length, 1⅜ inches; width, 1¼ inches; height, ⅞ inch.

Description.—The exact limitations of this species have in most of the earlier publications been very imperfectly designated. Other forms, even one of a different genus, have been included. The test is oblong, cordiform, and elevated. The upper surface is convex, with a well-defined anterior groove, narrow and slightly depressed at its head. On the posterior face the surface is truncated to the margin. The sides are rounded and inflated. The base is flat, except for the peristomial depression near the anterior margin and the central elevated region extending from the same to the posterior border.

The ambulacral areas are narrow and very unequal. The antero-lateral pair are large and curved backwards in their upper portions. The pores are very unequal; those of the anterior zone are small and near together, those of the posterior elongated, the external nearly

twice as large as the internal series (Pl. XXXIX, Fig. 2*e*). There are about 35 pairs of pores in the petaloidal portion of each poriferous zone.

The postero-lateral pairs are short and quite symmetrical in structure. There are 16 pairs of pores in the petaloidal portions of each poriferous zone.

The anterior unpaired ambulacrum is situated in the anterior groove, and is wider than the other areas. An elongated pore appears in the external rows on alternate plates. On the intervening plates the small rows are closely approximated (Pl. XXXIX, Fig. 2*f*). In the lower portion of each column the plates are large and oblong. A pair of minute pores occupy the lower outer corner of each.

The surface of the test is covered with a minute granulation, scattered among which are numerous small tubercles.

The apical disk is small and compact, and the four large genital plates are distinctly perforated. The right antero-lateral plate occupies the center of the body. The five small oculars are wedged in between the genitals (Pl. XXXIX, Fig. 2*g*).

The mouth opening is transversely oblong and situated in a depression.

The anal opening is situated high upon the truncated posterior margin, and is small and oval, acuminate below (Pl. XXXIX, Fig. 2*d*).

Related forms.—It seems not improbable that *Spatangus columbianum*, described by Lea in 1840, from the United States of Colombia, may prove to be identical, or at least very closely related to the Texan form. The indistinct figure shows a different arrangement of the pores in the antero-lateral ambulacra, but it is doubtful whether it can be depended upon for such details of structure. It seems unwise, however, to replace the term *texanus* when any doubt upon this point still remains.

Enallaster peruvianus, described by Gabb in 1876, from material obtained from Peru, seems to be identical.

Among the European Enallasters none apparently are closely related to *Enallaster texanus*.

Locality and geological horizon.—*Enallaster texanus* is found widely in Texas in the Fredericksburg formation of the Comanche series (lower Cretaceous). It is characteristic of the Comanche peak horizon.

Collections.—U. S. National Museum; Texas Geological Survey; Boston Society of Natural History; Prof. Robt. T. Hill.

ENALLASTER OBLIQUATUS Clark.

Plate XL, Figs. 1*a–l*.

Determinative characters.—Test oval, cordiform; upper surface convex, flattened and depressed anteriorly, elevated posteriorly; lower surface flat, with peristomial depression; apex forward of the center. Ambulacra narrow, unequal. Surface of the plates covered with small

tubercles and intervening microscopic granulation. Apical disk compact. Mouth opening transversely subpentagonal. Anal opening situated on truncated posterior margin.

Description.—This species has a broad cordiform test, that is flattened and slanting on the anterior upper surface, whence the name *obliquatus*. The anterior groove is deep, wider at its head, and cuts broadly into the anterior margin. The posterior portion of the test is elevated near the apex and obliquely truncated toward the margin. The sides are sloping anteriorly, fuller posteriorly. The base is flat with a deep peristomial depression.

The ambulacral areas are narrow and unequal. The antero-lateral pair are slightly depressed and curved backwards in the upper portion. The pores are unequal, those of the anterior zone small and near together, those of the posterior elongated, the exterior much more so than the anterior series (Pl. XL, Fig. 1*f*). There are about forty pairs of pores in each zone.

The postero-lateral pair are short and slightly depressed. The pores are more nearly equal and about twenty-four pairs are found in each zone. The single ambulacrum is placed in the anterior groove and is much wider than the paired ambulacra. The pores of the different plates vary in size and position (Pl. XL, Fig. 1*c*). The plates in the lower portions of the areas are large and oblong in form.

The surface of the test is covered with minute tubercles between which is a microscopic granulation. The apical disk is small and compact (Pl. XL, Fig. 1*i*).

The mouth opening is transversely subpentagonal (Pl. XL, Fig. 1*h*). The anal opening is oval and situated high on the truncated posterior margin (Pl. XL, Fig. 1*d*).

Related forms.—*Enallaster obliquatus* is separated from *E. texanus*, the only other representative of this genus from the Cretaceous deposits of the United States, by its broader more depressed form, more sunken anterior sulcus, and the lower position of the anal opening. It is closely related to *E. mexicanus*, described by Cotteau, in 1890, from material obtained from Mexico.

Locality and geological horizon.—This species is from the Fredericksburg formation of the Comanche series (lower Cretaceous) of Texas. It is characteristic of the alternating or Glen Rose beds of Austin and Glen Rose.

Collections.—U. S. National Museum; Texas Geological Survey.

EPIASTER D'Orbigny.

EPIASTER ELEGANS (Shumard).

Plate XLI, Figs. 1*a–b;* Plate XLII, Figs. 1*a–b;* Plate XLIII, Figs. 1*a–e.*

Hemiaster elegans Shumard, 1853. Rept. Expl. Red River of Louisiana in 1852, p. 210, Pl. 2, Figs. 4*a–4c.*

Toxaster elegans Gabb, 1859. Cat. Invert. Fossils Cretaceous, p. 19.

Toxaster elegans Meek, 1864. Smith. Misc. Coll., vol. 7 (177), p. 3.
Macraster texanus Roemer, 1888. Neues Jahrbuch für Min., Geol., u. Pal., Bd. I, pp. 191–195, Pl. 6, Figs. 1–4.
Epiaster elegans Clark, 1891. Johns Hopkins University Circulars, No. 87, p. 77.

Determinative characters.—Test large, oblong, cordiform, flattened both above and below; sides rounded, with a shallow anterior groove and truncated posterior margin. Ambulacra subpetaloidal, depressed; poriferous zones straight, pores with elongated, slit-like openings. Apical disk small, compact. Mouth opening transversely oval, situated near the anterior margin. Anal opening oval, situated on the truncated posterior margin.

Dimensions.—Length, 4 inches; width, 3¾ inches; height, 2 inches.

Description.—Roemer in 1888 established a new genus and species (*Macraster texanus*) for a form that is identical with *Hemiaster elegans* described by Shumard in 1853. The species properly belongs to the genus *Epiaster*. There does not seem to be a sufficiently wide difference between the characters assigned to *Macraster* and those properly belonging to *Epiaster* to warrant the acceptance of the former genus for the present species.

The test is very large and flattened on both the upper and lower surfaces. The sides are round. The groove on the anterior face is shallow and cuts the margin lightly. The posterior face is obliquely but not broadly truncated.

The ambulacral areas are nearly equal, depressed, with a distinct furrow on the upper surface (Pl. XLI, Fig. 1*a*). The poriferous zones are long, wide, and straight, and the pores consist of slit-like openings (Pl. XLIII, Figs. 1*b*, 1*c*). The zones are subpetaloidal on the upper surface, reaching quite to the upper margin of the rounded sides. The unpaired ambulacrum is narrower than the others; the pores are smaller and more closely approximated.

The surface of both areas is covered with minute tubercles, between which are microscopic granules (Pl. XLIII, Fig. 1*d*).

The apical disk is small, compact, and consists of four large perforated genital plates and five small oculars (Pl. XLIII, Fig. 1*c*).

The mouth opening is transversely oval and situated near the anterior margin (Pl. XLII, Fig. 1*a*).

The anal opening is large, oval, and situated on the truncated face of the posterior margin (Pl. XLII, Fig. 1*b*).

Related forms.—*Epiaster elegans* is most nearly related to *E. Whitei*, the single other American representative of this genus, but is separated from it by its great size, its excessively long subpetaloidal areas, and the position of the anal opening, which is on an obliquely truncated surface that opens downward, while on *E. Whitei* it is situated on a vertical face that opens upwards.

Locality and geological horizon.—*Epiaster elegans* is from the Washita formation of the Comanche series (lower Cretaceous) of Texas. It is

characteristic of the Fort Worth limestone, and is found at numerous localities between Denison and El Paso.

Collections.—U. S. National Museum; Johns Hopkins University; Boston Society of Natural History; Texas Geological Survey; Prof. Robt. T. Hill.

EPIASTER WHITEI Clark.

Plate XLIII, Figs. 2*a–d*; Plate XLIV, Figs. 1*a–g*.

Toxaster elegans Conrad, 1857. U. S. and Mex. Bound. Surv. Rept., vol. 1, pt. 2, p. 146, Pl. 21, Fig. 1*a–c*.[1]

Epiaster Whitei Clark, 1891. Johns Hopkins University Circulars, No. 87, p. 77.

Determinative characters.—Test small, cordiform; upper surface convex, elevated; lower surface flat; sides inflated; apex forward of the center. Ambulacra moderately broad; poriferous zones petaloidal, pores with elongated openings; antero-lateral pair bent slightly backward in upper part. Apical disk oval. Mouth opening transversely oval. Anal opening small, oval, situated high on posterior border.

Dimensions.—Length, 1½ inches; width, 1⅜ inches; height, ¾ inch.

Description.—This species has been frequently confounded with *Enallaster texanus* and *Epiaster elegans*. With the former it has little in common beyond a certain similarity in outward form, while the points of difference from the latter are less striking and will be shortly stated.

The test is small and cordiform. The upper surface is distinctly elevated, the apex occupying a point anterior to the center. The lower surface is flat with the exception of the peristomial depression. The sides are inflated with a well marked groove at the center of the anterior face and a prominent truncated surface on the posterior margin.

The ambulacral areas are moderately broad. The poriferous zones are subpetaloidal in their upper part, but this feature does not continue to the margin (Pl. XLIII, Fig. 2*c*). The pores in the paired ambulacra are all of about equal size and equally spaced. In the unpaired ambulacrum they are smaller and nearer together. The antero-lateral pair are bent slightly backward in their upper part. They are distinctly larger than the postero-laterals.

The interambulacral areas are prominent and the surface of the plates covered with minute tubercles and microscopic granules (Pl. XLIV, Fig. 1*c*).

The apical disk is small, compact, and consists of four large perforated genital plates and five oculars.

The mouth opening is transversely subpentagonal and situated near the anterior margin (Pl. XLIV, Figs. 1*b*, 1*f*).

The anal opening is small, oval, and situated high on the truncated posterior margin (Pl. XLIII, Fig. 2*b*).

Related forms.—In many particulars *Epiaster Whitei* is to be closely associated with *E. elegans*. It is, however, more elevated, the ambu-

[1] Figured under the name of *Holaster elegans*.

lacral furrows are shorter, and the anal opening is differently situated, as previously mentioned in the description of the latter species.

Locality and geological horizon.—*Epiaster Whitei* is from the Washita formation of the Comanche series (lower Cretaceous) of Texas. It is found in the Duck creek chalk of Denison, associated with *Hamites Fremontii* Marcou.

Collection.—U. S. National Museum.

HEMIASTER PARASTATUS (Morton).

Plate XLV, Figs. 1*a–m*.

Spatangus sp. Morton, 1830. Am. Jour. Sci., 1st ser., vol. 17, p. 286.
Spatangus cor-marinum (?) Morton, 1830. Am. Jour. Sci., 1st ser., vol. 18, p. 259, Pl. 3, Fig. 10.
Spatangus cor-marinum (?) Morton, 1830. Philadelphia Acad. Nat. Sci. Jour., 1st ser., vol. 6, p. 199.
Spatangus parastatus Morton, 1833. Am. Jour. Sci., 1st ser., vol. 23, p. 294.
Spatangus parastatus Morton, 1834. Synopsis Organ. Remains, Cretaceous, p. 77, Pl. 3, Fig. 21.
Hemiaster parastatus Agassiz and Desor, 1847. Cat. rais., p. 141.
Hemiaster parastatus d'Orbigny, 1847. Prodrome, vol. 2, p. 270.
Spatangus parastatus Bronn, 1848. Index Pal. vol. 1, p. 1160.
Hemiaster parastatus d'Orbigny, 1853–'56, Paléont. française, vol. 6, p. 265, Pl. 894, Fig. 4.
Hemiaster parastatus Desor, 1858. Synop. des Échinides fossiles, p. 373.
Holaster parastatus Gabb, 1859. Cat. Invert. Fossils, Cretaceous, p. 19.
Hemiaster (?) *parastatus* Meek, 1864. Smith. Misc. Coll., vol. 7 (177), p. 3.
Hemiaster parastatus Clark, 1891. Johns Hopkins University Circulars, No. 87, p. 77.

Determinative characters.—Test cordiform, inflated; upper surface elevated, with deep groove on anterior surface and sharp ridge posteriorly that is terminated by the flat, nearly vertical, truncated face of the posterior margin. Ambulacral petals depressed, the anterior pair twice as long as the posterior. Apical disk small, compact. Mouth opening with distinct, overhanging lip. Anal opening small, situated high on truncated surface.

Dimensions.—Length, 1½ inches; width, 1½ inches; height, 1⅛ inches.

Description.—This interesting and rather common form has a high, cordiform test, with deep anterior sulcus and high posterior ridge on the upper surface, the latter terminated by the high and nearly vertically truncated face of the posterior margin. The sides are rounded and inflated. The base is flat, with the exception of the peristomial depression.

The ambulacral areas are very unlike. The poriferous zones are distinctly petaloidal (Pl. XLV, Fig. 1*c*). The petals of the postero-lateral pair are short and broad. Those of the antero-lateral pair are bent backward at their center, depressed, and about twice the length of the postero-lateral pair. The pores are slightly elongated (Pl. XLV, Fig. 1*h*). The unpaired ambulacrum is very broad, the poriferous

zones far apart, and the pores small and approximated (Pl. XLV, Fig. 1*f*).

The surface is covered with small tubercles, between which are numerous microscopic granules (Pl. XLV, Figs. 1*f*, 1*g*, 1*i*, 1*l*, and 1*m*).

The apical disk is small and situated posteriorly to the center of the upper surface. The four genital plates are distinctly perforated and separated by the five small oculars (Pl. XLV, Fig. 1*n*).

The mouth opening is transversely arched and bilabiate. The lower lip projects prominently. The anal opening is small and situated high on the truncated surface of the posterior margin. The peripetalous fasciole is broad and distinct (Pl. XLV, Figs. 1*i*, 1*k*).

Related forms.—*Hemiaster parastatus* is most closely related to *H. ungula*, from which, however, it is separated by its deeper and broader anterior sulcus, more posterior position of the apical disk, and more inflated sides. It is apparently distinct from any of the many species described from European deposits.

Locality and geological horizon.—*H. parastatus* is from the yellow limestone of the middle marl bed (upper Cretaceous) of Timber creek, New Jersey, and also from the Ripley group (upper Cretaceous) of Alabama.

Collections.—Philadelphia Academy of Natural Sciences; American Museum of Natural History, New York; Johns Hopkins University.

HEMIASTER Desor.

HEMIASTER STELLA (Morton).

Plate XLVI, Figs. 1*a–d*.

Spatangus stella Morton, 1830. Am. Jour. Sci., 1st ser., vol. 18, p. 245, Pl. 3, Fig. 11.
Spatangus stella Morton, 1830. Philadelphia Acad. Nat. Sci. Jour., 1st ser., vol. 6, p. 200.
Spatangus stella Morton, 1834. Synop. Organ. Remains Cretaceous, p. 78, Pl. 3, Fig. 18.
Hemiaster stella Agassiz and Desor, 1847. Cat. rais., p. 141.
Hemiaster stella Desor, 1858. Synop. des Échinides fossiles, p. 373.
Hemiaster stella Gabb, 1859. Cat. Invert. Fossils, Cretaceous, p. 19.
Hemiaster (?) *stella* Meek, 1864. Smith Misc. Coll., vol. 7 (177), p. 3.
Hemiaster Wetherbyi de Loriol, 1887. Recueil Zoologique Suisse, f. 4, pp. 391–394, Pl. 17, Figs. 5–8.
Hemiaster incrassatus Clark, 1891. Johns Hopkins University Circulars, No. 87, p. 77.

Determinative characters.—Test small, oval, cordate, inflated, rounded before, truncated behind; upper surface elevated posteriorly, sloping anteriorly; anterior groove short, not reaching the ambitus. Ambulacra straight, depressed above. Apical disk excentric and posterior. Mouth opening bilabiate and near the anterior border. Anal opening small, high above posterior margin. Fasciole distinct.

Dimensions.—Length, 1 inch; width, $\frac{7}{8}$ inch; height, $\frac{5}{8}$ inch.

Description.—This form was originally described by Morton in 1830, and later, in 1833, considered by the same writer as the young of the species for which the name *parastatus* was then substituted. In presenting a preliminary notice of the present report the writer followed

Morton in this regard, but the examination of a larger amount of material shows that the new species, *H. incrassatus*, there described is only a large form of *H. stella*, so that it becomes necessary to discard the former term and employ both *H. stella* and *H. parastatus* of Morton. *Hemiaster Wetherbyi* de Loriol is apparently identical with *H. stella* Morton.

The test is small, oval, and cordate, and much elevated on the posterior portion of the upper surface. The whole test has a rounded, full outline, that is much increased by the absence of the usually deep anterior groove, which in *H. stella* does not reach the margin (Pl. XLVI, Fig. 1*a*). The posterior border is flatly and nearly vertically truncated.

The ambulacral areas are depressed in the petaloidal portions which, in the antero-lateral pair, are twice as long as in the postero-lateral. The poriferous zones are narrow; the pores have transverse slit-like openings. The unpaired ambulacrum is situated in the anterior groove.

The surface of the test is covered with innumerable small tubercles, between which is a microscopic granulation. The peripetalous fasciole is very distinct, oval, and passes with a regular curve about the ends of the petaloidal areas. The surface of the test is covered with minute tubercles, between which are microscopic granules. The apical disk is small, and situated posteriorly to the center of the upper surface of the test.

The mouth opening is transversely oval, bilabiate, and placed near the anterior margin. The anal opening is small, oval, and situated at the upper part of the truncated posterior margin.

Related forms.—*Hemiaster stella* is unique among American Hemiasters. The shallow anterior groove, that falls short of the margin, and the full elevated test readily distinguish it from other forms.

Locality and geological horizon.—*Hemiaster stella* is found in the yellow limestone of the middle marl bed (upper Cretaceous) of Timber creek, New Jersey.

Collections.—U. S. National Museum; Philadelphia Academy of Natural Sciences; Johns Hopkins University.

HEMIASTER UNGULA (Morton).

Plate XLVI, Figs. 2*a–g*.

Spatangus sp. Morton, 1830. Am. Jour. Sci., 1st ser., vol. 17, p. 286.
Spatangus ungula Morton, 1833. Am. Jour. Sci., 1st ser., vol. 23, p. 131, Pl. 10, Fig. 6.
Spatangus ungula Morton, 1834. Synop. Organ. Remains, Cretaceous, p. 78, Pl. 10, Fig. 6.
Micraster ungula Agassiz and Desor, 1847. Cat. rais., p. 141.
Spatangus ungula Bronn, 1848. Index Pal., vol. 1, p. 1161.
Holaster ungula Gabb, 1859. Cat. Invert. Fossils, Cretaceous, p. 19.
Hemiaster angula Clark, 1891. Johns Hopkins University Circulars, No. 87, p. 77.

Determinative characters.—Test oval, cordiform, elevated; upper surface inflated, elevated posteriorly; lower surface flat; sides sloping; anterior sulcus narrow and deep. Ambulacra narrow; poriferous zones straight, depressed, petaloidal. Peripetalous fasciole deeply bent

inward between the anterior and posterior paired ambulacra. Apical disk small, compact. Mouth opening transversely oval near anterior margin. Anal opening oval, supramarginal.

Dimensions.—Length, 1¼ inches; width, 1⅛ inches; height, ⅞ inch.

Description.—This species has an oval, cordate test, that is very much elevated in the posterior portion. Anteriorly the upper surface slopes rapidly, so that the margin is much thinned down, losing the full round aspect of the previously described forms. The sharp ridge on the posterior portion of the test is terminated by a nearly vertical truncation of the posterior margin. The base is flat, save for the peristomial depression.

The ambulacral areas are narrow. The poriferous zones are petaloidal, straight, and deeply depressed on the upper surface. The unpaired ambulacrum is placed in the anterior sulcus and but slightly exceeds the other areas in width. The petals of the antero-lateral pair are twice the length of the postero-lateral. The pores of the paired ambulacra are elongated and separated (Pl. XLVI, Fig. 2*e*), those of the single ambulacrum small, oval, and approximated (Pl. XLVI, Fig. 2*f*).

The surface of the test is covered with small tubercles, between which are numerous minute granules. The peripetalous fasciole is distinct and bent outwards between the anterior and posterior paired ambulacra.

The apical disk is small and situated posterior to the center of the upper surface. The antero-lateral genital plate is very large and widely separates the posterior pair of oculars. The postero-lateral genitals have large perforations (Pl. XLVI, Fig. 2*g*).

The mouth opening is transversely oval, bilabiate, with a prominently projecting lower lip. The anal opening is large and situated at the upper part of the truncated face of the posterior margin.

Related forms.—It is separated from *Hemiaster parastatus*, with which it is found, by the narrower anterior groove, more central apical disk, less inflated sides, sharper posterior keel, and straight ambulacral plates.

Locality and geological horizon.—*Hemiaster ungula* is from the yellow limestone of the middle marl bed (upper Cretaceous) of Timber creek, New Jersey.

Collections.—Philadelphia Academy of Natural Sciences; American Museum of Natural History, New York.

HEMIASTER TEXANUS Roemer.

Plate XLVII, Figs 1*a–i*.

Hemiaster texanus Roemer, 1849. Texas, etc., p. 393.
Hemiaster texanus Roemer, 1852. Die Kreidebildungen von Texas, p. 85. Pl. 10, Fig. 4.
Hemiaster americanus Giebel, 1853. Jahresber. d. Naturw. Ver. in Halle, p. 372, 373.
Hemiaster texanus Gabb, 1859. Cat. Invert. Fossils, Cretaceous, p. 19.
Hemiaster texanus Meek, 1864. Smith. Misc. Coll., vol. 7 (177), p. 3.
Hemiaster texanus Clark, 1891. Johns Hopkins University Circulars, No. 87, p. 77.

Determinitive characters.—Test oval, cordate, declining anteriorly, elevated slightly posteriorly; anterior sulcus broad and deep, producing groove in margin. Ambulacra broadly depressed on upper surface; antero-lateral pair bent backward in upper part; unpaired ambulacrum very broad. Apical disk compact, the four genitals distinctly perforated. Mouth opening large, transversely oval, bilabiate. Anal opening large, oval, at center of truncated surface of posterior margin.

Dimensions.—Length, 1¼ to 2 inches; width, 1⅛ to 1⅜ inches; height, ⅝ to 1 inch.

Description.—This important species is broadly cordate and slightly depressed on the upper surface; base flat. Posterior to the apex there is a sharp ridge that declines gradually toward the obliquely truncated margin. Anteriorly the upper surface declines toward the anterior border.

The ambulacral areas are broad, very unequal, and depressed in the petaloidal portions. The poriferous zones are broad, the pores of the paired ambulacra elongated (Pl. XLVII, Fig. 1*e*), those of the single ambulacrum round and approximated (Pl. XLVII, Fig. 1*f*). The petals of the antero-lateral pair are bent backward in their upper part and are nearly twice the width of the postero-lateral pair. The single ambulacrum is very broad, the poriferous zones widely separated.

The surface of the test is covered with small tubercles that are perforated and for the most part crenulated (Pl. XLVII, Fig. 1*h*, 1*i*). A microscopic granulation fills the intertubercular space.

The apical disk is small and compact and situated near the center. The four genital plates are distinctly perforated; the antero-lateral is larger than the others and serves as the madreporite. The five oculars are wedged between the genitals and are deeply cut by the upper portions of the ambulacra (Pl. XLVII, Fig. 1*g*).

The mouth opening is large, transversely oval, and bilabiate. The anal opening is large, oval, and situated in the center of the truncated surface of the posterior margin (Pl. XLVII, Fig. 1*d*).

Related forms.—Under the name of *Hemiaster americanus*, Giebel published the description of a new species of Hemiaster, in 1853, that he states can be with difficulty distinguished from *H. texanus*. It is considered identical in the present report. The differences seem hardly to warrant the establishment of a new species. *Periaster australis*, described by Gabb, from Peru, so far as the figures and description show, must be a Hemiaster, and to all appearances is closely allied if not identical with *H. texanus*.

Locality and geological horizon.—*Hemiaster texanus* is from the upper division of the Cretaceous of Texas. It is characteristic of the Austin chalk.

Collections.—U. S. National Museum; Prof. Robt. T. Hill.

HEMIASTER HUMPHREYSANUS Meek and Hayden.

Plate XLVIII, Figs. 1*a–f*.

Hemiaster (?) *Humphreysanus* Meek and Hayden, 1857. Philadelphia Acad. Nat. Sci. Proc., vol. 9, pp. 147, 148.
Hemiaster (?) *Humphreysanus* Gabb, 1859. Cat. Invert. Fossils Cretaceous, p. 19.
Hemiaster (?) *Humphreysanus* Meek, 1864. Smith. Misc. Coll., vol. 7 (177), p. 3.
Hemiaster Humphreysanus Meek. U. S. Geol. Surv. of the Territories, vol. 9, pp. 5, 6, Pl. 10, Figs. 1*a–g*.
Hemiaster Humphreysanus Clark, 1891. Johns Hopkins University Circulars, No. 87, p. 77.

Determinative characters.—Test oval, cordate; upper surface high, flat, with broad, vertical truncation on posterior margin, and long anterior groove; base flat; sides rounded. Ambulacra in deep furrows that reach to the edge of the elevated sides. Apical disk large and compact, posteriorly situated. Mouth opening small, transversely oval, and bilabiate. Anal opening oval, situated high on posterior margin.

Dimensions.—Length, 1⅛ inches; width, 1⅛ inches; height, ¾ inch.

Description.—The absence of distinct fascioles on the type specimens of this species caused Meek and Hayden to place it doubtfully in the genus Hemiaster, to which beyond doubt it belongs. The test is full, the sides rounded, and the high upper surface distinctly flattened. The base is also flat, with the exception of the peristomial depression. The situation of the apex so far posterior to the center of the upper surface produces a long anterior sulcus, that grooves the anterior margin. A high, vertically truncated surface terminates the posterior margin.

The ambulacral areas are broad, very unequal, and deeply depressed on the upper surface. The petals of the postero-lateral pair are very short, those of the antero-lateral very long, the latter quite three times the length of the former. The unpaired ambulacrum occupies the long anterior sulcus. The antero-lateral pair are bent backward in the upper part and forward in the lower. The poriferous zones are broad, the pores distinct and oval (Pl. XLVIII, Figs. 1*e*, 1*f*). Since much of the surface of the test has suffered removal the character of the tubercles and granules can not be fully determined.

The apical disk, which has been largely destroyed, was large, compact, and situated far posterior to the center of the upper surface.

The mouth opening is small and situated near the anterior margin. The anal opening is oval and situated on the vertically truncated surface of the posterior margin (Pl. XLVIII, Fig. 1*d*).

Related forms.—*Hemiaster Humphreysanus* is a unique form, that is not closely related to any species of Hemiaster hitherto described.

Locality and geological horizon.—This species is from the Fort Pierre formation (upper Cretaceous) of Meek and Hayden and was found 150 miles from the mouth of the Yellowstone river in Montana.

Collection.—U. S. National Museum.

HEMIASTER DALLI Clark.

Plate XLVIII, Figs. 2*a–e*.

Hemiaster Dalli Clark, 1891. Johns Hopkins University Circulars, No. 87, pp. 77.

Determinative characters.—Test cordate, subhexagonal, depressed; upper surface with sharp ridges between the ambulacral furrows; base flat; sides rapidly declining; anterior margin deeply grooved. Ambulacra unequal, very deeply depressed on petaloidal portions; antero-lateral pair much bent in upper part. Mouth opening transversely oval, near anterior margin. Anal opening oval, situated on vertically truncated surface of posterior margin.

Dimensions.—Length, 1¾ inches; width, 1⅝ inches; height, ⅝ inch.

Description.—This species is much depressed, with distinct marginal angles that give it a subhexagonal outline. Prominent ridges cross the upper surface between the ambulacral furrows. The anterior sulcus cuts deeply into the test and grooves the anterior margin. The sides decline rapidly to the flattened base. The low posterior surface has a nearly vertical truncation of small area.

The ambulacral areas are very deeply depressed on the upper surface, a feature much more pronounced than in any other American species. The antero-lateral pair are bent backward in their upper part, and have long, deep furrows. The postero-lateral pair are about one-half the length of the anterior pair. The single ambulacrum is situated in the broad, deep, anterior sulcus. The poriferous zones in the paired ambulacrum are broad, the pores oval, those of each pair united by a shallow furrow (Pl. XLVIII, Fig. 2*e*). In the unpaired ambulacrum the poriferous zones are narrow, the pores small and approximated.

The surface is covered with small tubercles with sunken areolas that increase in size toward the base, where they are large, with distinctly perforated mamelons and crenulated bosses. A fine microscopic granulation fills the interspaces.

The apical disk is sunken, small, and posterior to the center of the upper surface.

The mouth opening is transversely oval and close to the anterior margin.

The anal opening is oval and situated on the truncated surface of the posterior border (Pl. XLVIII, Fig. 2*d*).

Related forms.—The very deep ambulacral furrows and angular outline readily separate *Hemiaster Dalli* from any other American species. It is not closely allied to any European form.

Locality and geological horizon.—This form is from the Washita formation of the Comanche series (lower Cretaceous) of Bexar county, Texas.

Collection.—U. S. National Museum.

HEMIASTER CALIFORNICUS Clark.

Plate XLIX, Figs. 1*a–c*.

Hemiaster californicus Clark, 1891. Johns Hopkins University Circulars, No. 87, p. 77.

Determinative characters.—Test small, subquadrate, depressed; upper surface flat, with shallow anterior sulcus, sloping sides, and low truncated posterior margin; lower surface flat. Ambulacra depressed, in shallow furrows. Apical disk small, posterior to center. Mouth opening transversely oval near anterior margin. Anal opening situated on the low truncated surface of the posterior margin.

Dimensions.—Length, 1 inch; width, 1 inch; height, ¼ inch.

Description.—This form, the single representative of the Echinodermata thus far obtained from the Cretaceous deposits of California, has the details of its structure poorly preserved in the specimens examined, although it belongs, beyond much doubt, to the genus *Hemiaster*. The test is small, much depressed, and subquadrate in ambital outline. It is broader anteriorly, with a feeble groove in the center of the anterior margin. The posterior portion of the test is but slightly more elevated than the anterior, and the truncated margin is low and narrow. The base is flat, with the exception of the peristomial depression.

The ambulacral areas are but slightly depressed in the petaloidal portions. The poriferous zones are broad, and the oval pores are united by shallow furrows (Pl. XLIX, Fig. 1*a*).

The apical disk is small and situated slightly forward of the center.

The mouth opening is transversely oval and situated near the anterior margin (Pl. XLIX, Fig. 1*b*). The anal opening is small, oval, and situated on the low, truncated surface of the posterior border.

Related forms.—On account of its shallow ambulacral furrows, *Hemiaster californicus* may be compared to *H. Humphreysanus*, but is readily separated from it by means of its more central apical disk and its depressed form. It is a very unique species.

Locality and geological horizon.—*H. californicus* is from Redding, Shasta county, California, in deposits that have been referred to the Chico group (upper Cretaceous).

Collection.—U. S. National Museum.

HEMIASTER CALVINI Clark.

Plate XLIX, Figs. 2*a–i*.

Determinative characters.—Test oval, cordate, inflated; upper surface elevated; lower surface flat; posterior margin obliquely truncated. Ambulacra moderately depressed on the upper surface. Mouth opening transversely oval. Anal opening oval, high on truncated posterior border.

Dimensions.—Length, 1½ inches; width, 1¼ inches; height, ⅞ inch.

Description.—This species has an elevated test that is oval, cordate,

and broadly truncated on the posterior margin. The anterior sulcus is shallow, and produces but a feeble groove on the anterior margin. The base is flat.

The ambulacral areas are narrow. The poriferous zones are broad; the petals moderately depressed and of good length; the pores in the petaloidal portions of the paired ambulacra elongated, slit-like (Pl. XLIX, Fig. 2*e*), those of the unpaired ambulacrum small and approximated (Pl. XLIX, Fig. 2*g*). Beyond the petals the pores are very small, and occupy the lower outside corner of each plate (Pl. XLIX, Fig. 2*f*).

The surface of the plates is covered with small perforated tubercles, rather widely scattered, between which a microscopic granulation intervenes. The peripetalous fasciole is indistinct.

The apical disk is small, compact, and nearly central (Pl. XLIX, Fig. 2*i*).

The mouth opening is small, transversely oval, and situated at a distance from the margin.

The anal opening is oval and situated high on the truncated surface of the posterior margin.

Related forms.—*Hemiaster Calvini* is most closely related to *H. texanus*, from which, however, it is separated by its more elevated form and small, narrow, anterior sulcus. The apical disk is also more excentric.

Locality and geological horizon.—*Hemiaster Calvini* is from the Shoal creek limestone at the top of the Comanche series (lower Cretaceous) of Texas. It is found in Travis county.

Collections.—U. S. National Museum; University of Iowa.

LINTHIA Merian.

LINTHIA TUMIDULA Clark.

Plate L, Figs. 1*a–i*.

Linthia tumidula Clark, 1891. Johns Hopkins University Circulars, No. 87, p. 77.

Determinative characters.—Test oval, cordiform, elevated; apex central; posterior border obliquely truncated, anterior portion grooved by narrow sulcus; sides sloping. Ambulacral furrows long, straight, depressed; poriferous zones broad, pores oval. Apical disk small, nearly central. Anal opening on truncated posterior border. Peripetalous and lateral fascioles distinct.

Dimensions.—Length, 2⅛ inches; width, 2 inches; height, 1⅛ inches.

Description.—This large form has an elevated test, with flattened, sloping sides, oval outline, and a narrow, moderately depressed anterior sulcus that grooves the anterior margin. The base is flat, except for the peristomial depression.

The ambulacral areas are narrow and furrow for a long distance the upper surface of the test to a moderate depth. The poriferous zones

are broad and straight. The pores are large and oval, and those of each pair connected by a shallow furrow (Pl. L, Fig. 1*f*). The antero-lateral petals reach far down the sloping sides and are about one and one-half times as long as the postero-lateral pair.

The surface of the test is covered with minute, perforated tubercles that are much larger on the base than on the upper surface. A microscopic granulation fills the space between the tubercles (Pl. L, Fig. 1*i*). Both the peripetalous and lateral fascioles can be readily traced.

The apical disk is small, nearly central, and slightly depressed (Pl. L, Fig. 1*g*).

The mouth opening is transversely oval and situated near the anterior margin. The anal opening is small, oval, and situated but a short distance above the posterior margin (Pl. L, Fig. 1*d*).

Related forms.—*L. tumidula* is the only representative of the genus from American deposits. It is not closely allied to any species described elsewhere.

Locality and geological horizon.—*Linthia tumidula* is from the yellow limestone of the middle marl bed (upper Cretaceous), of Timber creek, New Jersey.

Collections.—American Museum of Natural History, New York; BostonSociety of Natural History.

DOUBTFUL AND UNRECOGNIZED SPECIES.

With few exceptions the writer has had an opportunity of examining the type forms of previous writers upon the Mesozoic Echinodermata of the United States, and as a result *Cassidulus abruptus* Conrad, *Arbacia* sp. Roemer, and Diadema sp. Roemer are the only species that can not be identified. Three other species—two from lack of generic characters (*Pygurus* (*?*) *geometricus* (Morton) and *Cidaris nahalakensis* de Loriol), the third (*Discoidea occidentale* Gabb) because of probable foreign origin—are not included, although the synonymy of each is given for purposes of reference. A single specific name (*Holectypus simplex* Roemer) has found its way into the literature from its use in Gabb's Catalogue, although probably mentioned by mistake.

CASSIDULUS ABRUPTUS Conrad.

Cassidulus abruptus Conrad, 1860. Philadelphia Acad. Nat. Sci. Jour., new ser., vol. 4, p. 291.

Cassidulus abruptus Clark, 1891. Johns Hopkins University Circulars, No. 87, p. 77.

This species, originally described by Conrad in 1860, but not figured, is from Tippah county, Mississippi. It has not been recognized in material examined by the writer, so that its relations to the other forms described are not known.

PYGURUS (?) GEOMETRICUS (Morton).

Clypeaster sp. Morton, 1830. Philadelphia Acad. Sci. Jour., 1st ser., vol. 6, p. 202.

Clypeaster geometricus Morton, 1833. Am. Jour. Sci., 1st ser., vol. 24, p. 131, Pl. 10, Fig. 9.

Clypeaster geometricus Morton, 1831. Synop. Organ. Remains, Cretaceous, p. 76, Pl. 10, Fig. 10.
Pygurus geometricus Agassiz and Desor, 1847. Cat. rais., p. 141.
Pygurus geometricus d'Orbigny, 1847. Prodrome, vol. 2, p. 270.
Clypeaster geometricus Bronn, 1848. Index Pal. vol. 1, p. 312.
Pygurus geometricus d'Orbigny, 1853–'60. Paléont. française, vol. 6, p. 313, Pl. 920, Fig. 4.
Pygurus geometricus Desor, 1858. Synop. des Échinides fossiles, p. 313.
Clypeaster geometricus Gabb, 1859. Cat. Invert. Fossils, Cretaceous, p. 18.
Pygurus (?) geometricus Clark, 1891. Johns Hopkins University Circulars, No. 87, p. 77.

The type of this species was examined by the writer, but its state of preservation (that of a poor cast) is such that its generic relations cannot be with certainty determined. Until further material is obtained it seems best to defer its recognition.

Although originally described by Morton as a Clypeaster, it has been referred to the genus Pygurus by Agassiz, d'Orbigny, and Desor. The single specimen was obtained from the lower marl bed (upper Cretaceous) of the Delaware and Chesapeake canal.

Cidaris nahalakensis de Loriol.

Cidaris nahalakensis de Loriol, 1887. Recueil Zoölogique suisse, tome 4, pp. 388, 389, Pl. 17, Figs. 3–4.

The present species is based by P. de Loriol upon fragment of spines obtained from the Rotten limestone of the upper Cretaceous of Nahalak, Kemper county, Mississippi. The acceptance of the species is reserved until fuller material has been obtained. Similar spines have been recognized by the writer from other localities, but whether they represent an independent species or one hitherto described is not yet clear.

Discoidea occidentale Gabb.

Discoidea occidentale Gabb, 1860. Philadelphia Acad. Nat. Sci. Jour., new ser., vol. 4. p. 398, Pl. 68, Figs. 42–44.
Discoidea occidentale Gabb, 1876. Philadelphia Acad. Nat. Sci. Proc., vol. 28, p. 323.
Discoidea occidentale Clark, 1891. Johns Hopkins University Circulars, No. 87, p. 77,

When first described in 1860 Gabb referred this form to the Cretaceous of Oregon, but later, in 1876, thought he might have been mistaken in the locality and mentioned Peru as its probable origin. In view of this doubt it is omitted from the list of species.

? Holectypus simplex Shumard.

? Holectypus simplex Shumard (description unknown).
Holectypus simplex Meek, 1861. Smith Misc. Coll., vol. 7 (177), p. 2.
? Holectypus simplex Clark, 1891. Johns Hopkins University Circulars, No. 87, p. 77.

Meek includes *Holectypus simplex* Shumard among his list of American Cretaceous Echinodermata and gives Texas as the locality. As a careful search of the literature and extended correspondence with those familiar with Shumard's writings fail to elicit any information upon this point, the writer is of the opinion that the reference to this species by Meek is a mistake. No such species was probably ever described.

GEOLOGICAL DISTRIBUTION.

	Trias.	Jura.	Lower Cretaceous.	Upper Cretaceous.
CRINOIDEA:				
UINTACRINIDÆ—				
Uintacrinus socialis Grinnell				×
APIOCRINIDÆ—				
Bourgueticrinus alabamensis de Loriol				×
PENTACRINIDÆ—				
Pentacrinus asteriscus Meek and Hayden		×		
Pentacrinus Whitei Clark	× (?)	×		
Pentacrinus Bryani Gabb				×
ASTEROIDEA:				
OPHIURIDÆ—				
Ophioglypha bridgerensis (Morton)				×
Ophioglypha texana Clark			×	
STELLERIDÆ—				
Asterias (?) dubium Whitfield		×		
Goniaster mammillata Gabb				×
ECHINOIDEA:				
EUECHINOIDEA—				
REGULARES—				
CIDARIDAE—				
Cidaris taylorensis Clark		×		
Cidaris californicus Clark		×		
Cidaris splendens Morton				×
Cidaris Walcotti Clark				×
Cidaris texanus Clark			×	
Leiocidaris hemigranosus (Shumard)			×	
SALENIDAE—				
Salenia texana Credner			×	
Salenia tumidula Clark				×
Salenia bellula Clark				×
DIADEMATIDÆ—				
Hemicidaris intumescens Clark		×		
Pseudodiadema Emersoni Clark		×		
Pseudodiadema diatretum (Morton)				×
Pseudodiadema texanum (Roemer)			×	
Diplopodia texanum (Roemer)			×	
Diplopodia Hilli Clark				×
Coptosoma speciosum Clark				×
Coptosoma Mortoni (de Loriol)				×
Goniopygus Zitteli Clark			×	
ECHINIDÆ—				
Psammechinus cingulatus Clark				×
Stomechinus Hyatti Clark		×		
Pedinopsis Pondi Clark				×
IRREGULARES—				
ECHINOCONIDÆ—				
Holectypus planatus Roemer			×	
CASSIDULIDÆ—				
Pyrina Parryi Hall			×	
Botriopygus alabamensis Clark				×
Echinobrissus expansus Clark				×
Echinobrissus texanus Clark				×
Trematopygus crucifer (Morton)				×
Catopygus oviformis Conrad				×
Catopygus pusillus Clark				×
Cassidulus florealis (Morton)				×
Cassidulus æquoreus Morton				×
Cassidulus micrococcus Gabb				×
Cassidulus subquadratus Conrad				×
Cassidulus subconicus Clark				×
Cassidulus porrectus Clark				×
Cassidulus Stantoni Clark				×
HOLASTERIDAE—				
Ananchytes ovalis Clark				×
Cardiaster cinctus (Morton)				×
Holaster simplex Shumard			×	
SPATANGIDAE—				
Enallaster texanus (Roemer)			×	
Enallaster obliquatus Clark			×	
Epiaster elegans (Shumard)			×	
Epiaster Whitei Clark			×	
Hemiaster stella (Morton)				×
Hemiaster parastatus (Morton)				×
Hemiaster ungula (Morton)				×
Hemiaster texanus Roemer				×
Hemiaster Humphreysanus Meek and Hayden				×
Hemiaster Dalli Clark			×	
Hemiaster californicus Clark				×
Hemiaster Calvini Clark			×	
Linthia tumidula Clark				×

CATALOGUE OF SPECIFIC NAMES EMPLOYED BY WRITERS UPON THE MESOZOIC ECHINODERMATA OF THE UNITED STATES.

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PLATES.

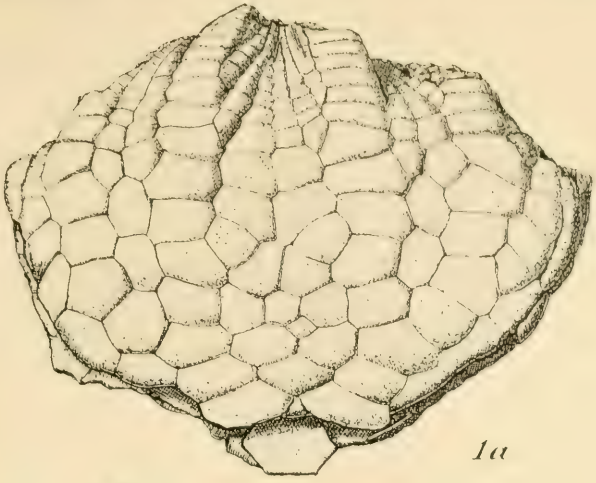
In consequence of a mistake in drawing, the forms the upper and lower views of the tests of the Holasteridæ and Spatangidæ are inverted on the plates.

PLATE I.

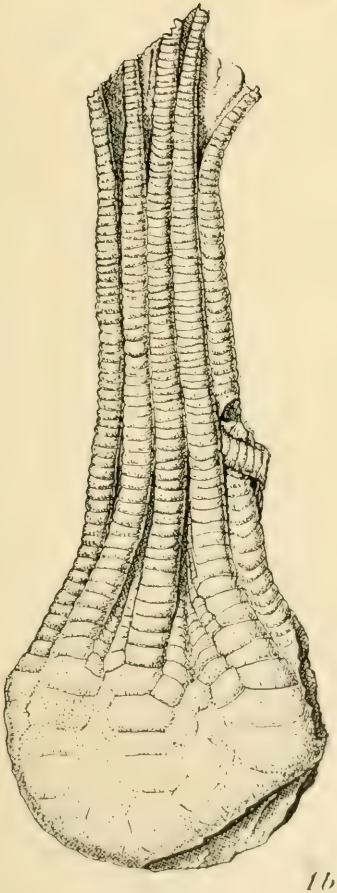
PLATE I.

UINTACRINUS SOCIALIS Grinnell (page 21).

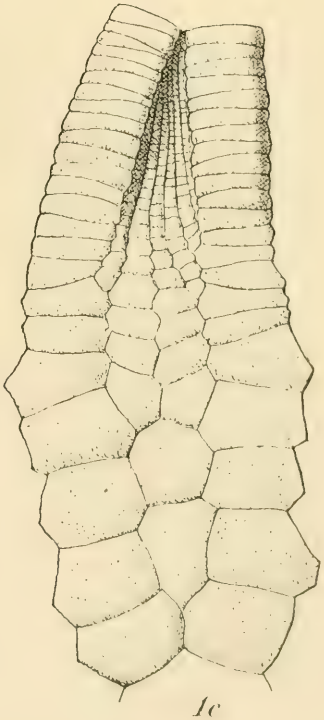
Fig. 1*a*. Laterial view of the test, with interradial area central, natural size.
1*b*. Test with arms.
1*c*. A radial area, magnified two diameters.



1a



1b



1c

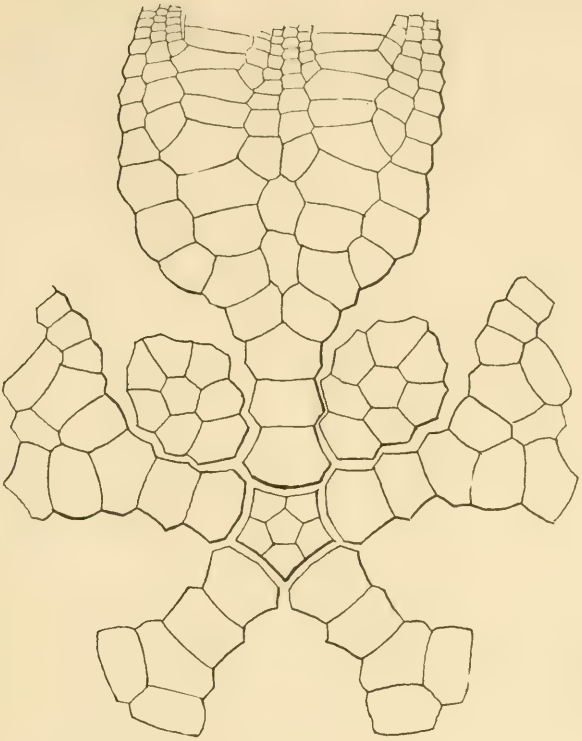
UINTACRINUS.

PLATE II.

PLATE II.

UINTACRINUS SOCIALIS Grinnell (page 21).

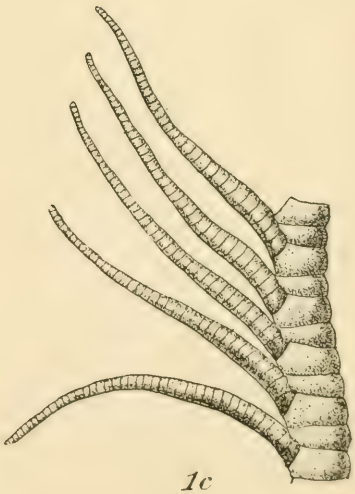
Fig. 1*a*. Diagram showing the structural arrangement of the plates in the test.
1*b*. Specimen showing basals and portions of radial and interradial areas.
1*c*. Lateral view of arm with attached pinnules.
1*d*. Zizygial surface of brachial plate.
1*e*. Articular surface of brachial plate.



1a

1d

1e



1c

1b

UINTACRINUS.

PLATE III.

PLATE III.

BOURGUETICRINUS ALABAMENSIS De Loriol (page 25).

Fig. 1*a*. Side view of the basal cone magnified five diameters.
1*b*. Upper surface magnified six diameters.
1*c*. Lower surface magnified six diameters.

PENTACRINUS ASTERISCUS Meek & Hayden (page 26).

Fig. 2*a*. Column with attached pinnules.
2*b*. Upper surface of a detached plate of the column.
2*c*. Lateral view of a portion of the column.
2*d*. Enlarged pinnule.

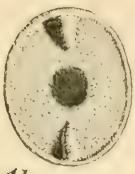
PENTACRINUS BRYANI Gabb (page 28).

Fig. 3*a*. Upper surface of a detached plate of the column.
3*b*. Lateral view of a portion of the column.

PENTACRINUS WHITEI Clark (page 27).

Fig. 4*a*. Upper surface of a detached plate of the column.
4*b*. Ditto.
4*c*. Lateral view of a portion of the column.

1a

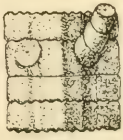


1b

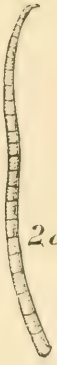
1c

2a

2b



2c



2d

3a

3b

4a

4c

4b

BOURGUETICRINUS AND PENTACRINUS.

PLATE IV.

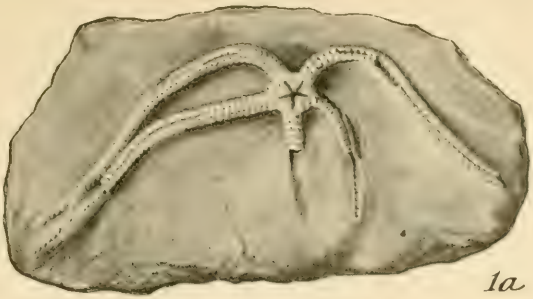
PLATE IV.

OPHIOGLYPHA BRIDGERENSIS (Meek) (page 29).

Fig. 1*a*. Skeleton, natural size.
1*b*. Enlarged view of a portion of the upper surface.
1*c*. Enlarged view of a portion of the lower surface.

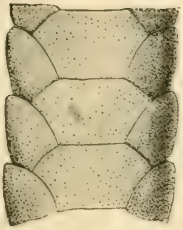
OPHIOGLYPHA TEXANA Clark (page 30).

Fig. 2*a*. Skeleton.
2*b*. Enlarged view of a portion of the upper surface.

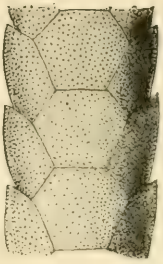


1a

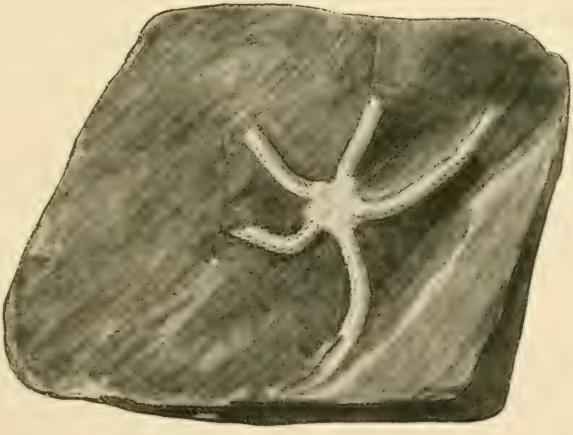
1c



1b



2b



2a

OPHIOGLYPHA.

PLATE V.

PLATE V.

GONIASTER MAMMILLATA Gabb (page 32).

Fig. 1*a–g*. Views from various sides of four different plates; magnified two diameters.
1*h*. Greatly magnified surface of plate.

ASTERIAS DUBIUM Whitfield (page 31).

Fig. 2. Gutta-percha cast of three individuals.

1a

1c

1d

1b

1h

1e

1f

1g

2

GONIASTER AND ASTERIAS.

PLATE VI.

PLATE VI.

CIDARIS CALIFORNICUS Clark (page 36).

Fig. 1*a*. Spine, enlarged.
1*b*. Ditto.
1*c*. Articular surface of 1*b*, much enlarged.

CIDARIS TAYLORENSIS Clark (page 35).

Fig. 2*a*. Fragment of two contiguous interambulacral plates of the same series.
2*b*. Spine.

CIDARIS SPLENDENS Morton (page 33).

Fig. 3*a*. Portion of test, natural size.
3*b*. Interambulacral plate, magnified two diameters.
3*c*. Ambulacral area, highly magnified.
3*d*. Tubercle, enlarged.
3*e*. Spine.
3*f*. Base of same much enlarged.
3*g*. Articular surface of spine.

CIDARIS WALCOTTI Clark (page 37).

Fig. 4*a*. Portion of test, natural size.
4*b*. Interambulacral plates, enlarged.
4*c*. Ambulacral area, highly magnified.
4*d*. Tubercle, enlarged.

1a

2a

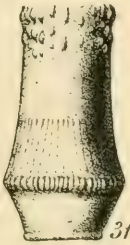
1b

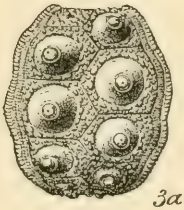
1c

2b

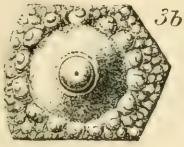
3d

3g

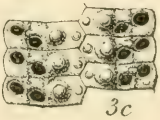

3f

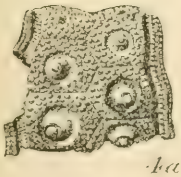

3a

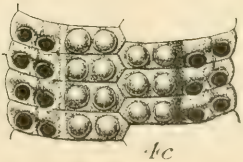
3e

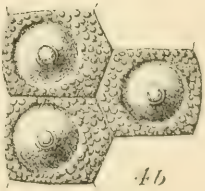

3b

4d


3c


4a


4c


4b

CIDARIS.

PLATE VII.

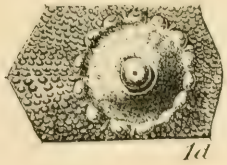
PLATE VII.

CIDARIS TEXANUS Clark (page 36).

Fig. 1*a*. Test restored, natural size.
1*b*. View showing the arrangement of the interambulacral plates in the vicinity of the apical disk, with adjacent ambulacral plates.
1*c*. Portion of ambulacral area, enlarged.
1*d*. Interambulacral plate, enlarged.
1*e*. Tubercle, much enlarged.

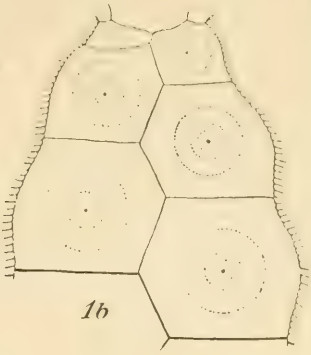
LEIOCIDARIS HEMIGRANOSUS (Shumard) (page 38).

Fig. 2*a*. Interambulacral plate.
2*b*. Portion of ambulacral area, enlarged.
2*c*. Tubercles, magnified two diameters.
2*d*. Apical disk, enlarged.

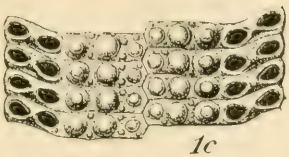


1d

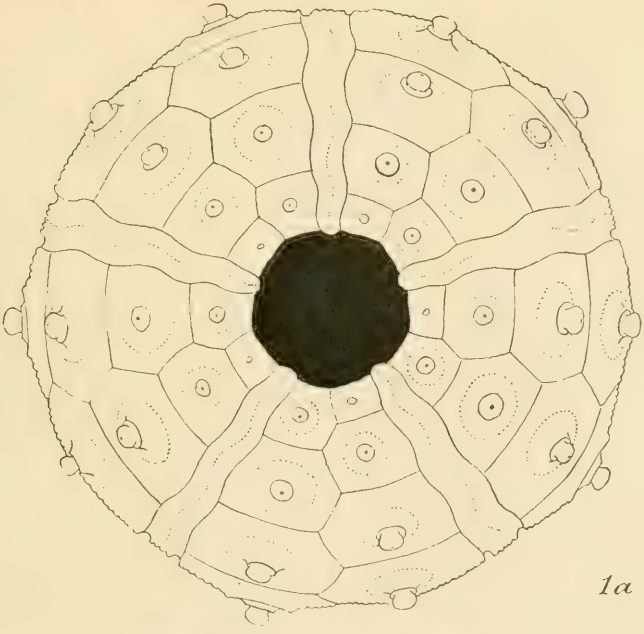
1e



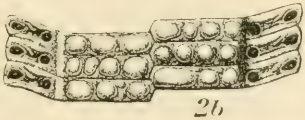
1b



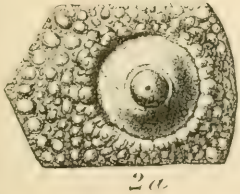
1c



1a

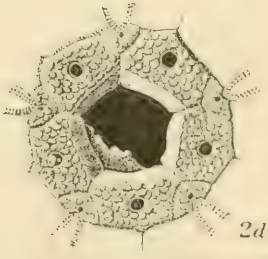


2b



2a

2c



2d

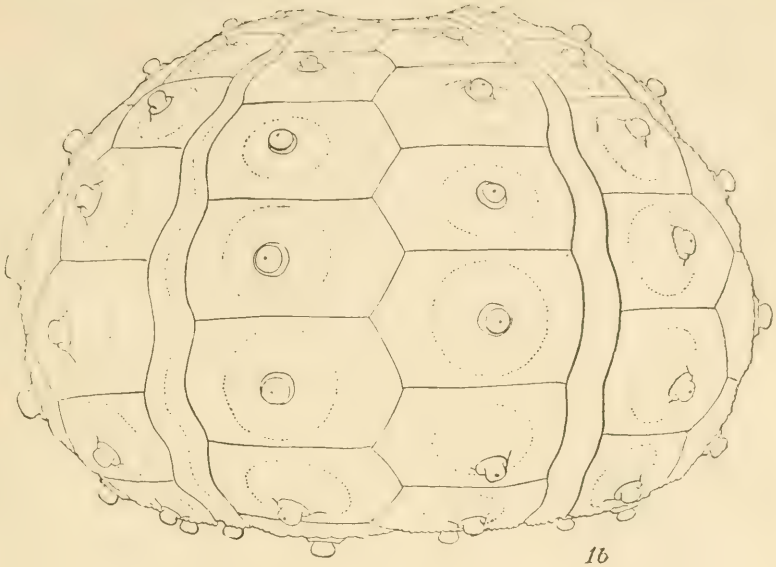
CIDARIS AND LEIOCIDARIS.

PLATE VIII.

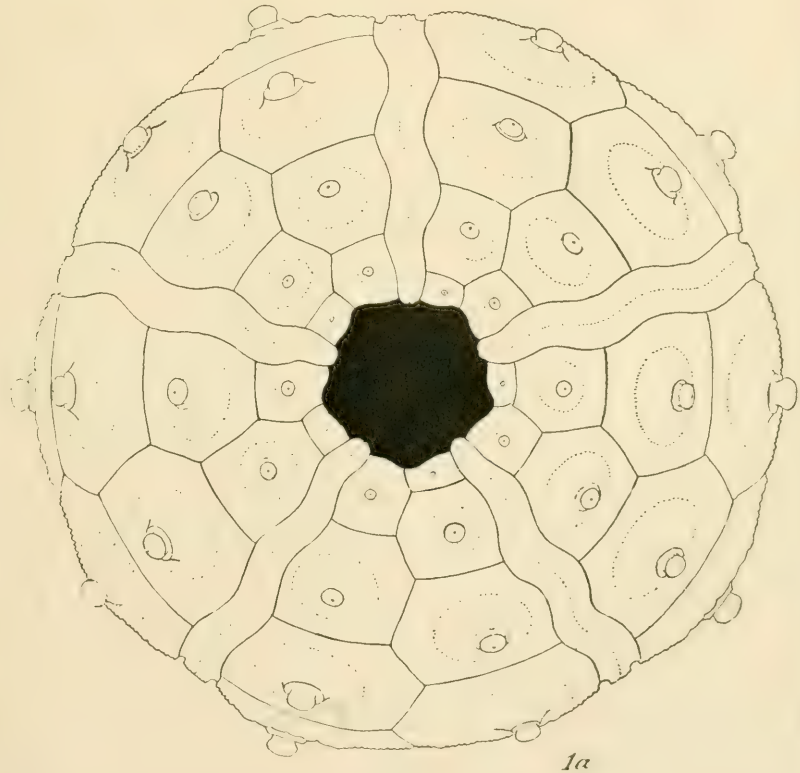
PLATE VIII.

LEIOCIDARIS HEMIGRANOSUS (Shumard) (page 38).

Fig. 1*a*. Upper surface of the test, natural size.
1*b*. Lateral view of the same.



1b



1a

LEIOCIDARIS.

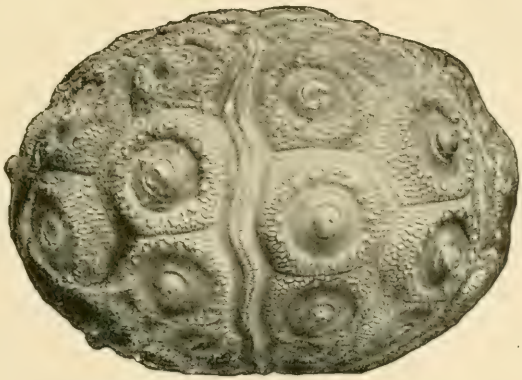
PLATE IX.

PLATE IX.

LEIOCIDARIS HEMIGRANOSUS (Shumard) (page 38).

Fig. 1*a*. Upper surface of the test.
1*b*. Lower surface of the test.
1*c*. Lateral view of the same.

1b



1c

1a

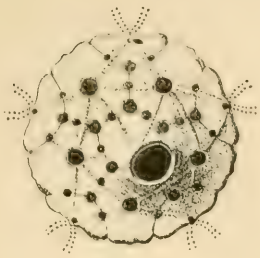
LEIOCIDARIS.

PLATE X.

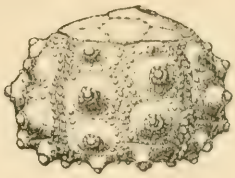
PLATE X.

SALENIA TEXANA Credner (page 40).

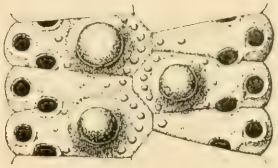
Fig. 1*a*. Upper surface of the test, natural size.
1*b*. Under surface of the same.
1*c*. Lateral surface of the same.
1*d*. Interambulacral area, magnified two diameters.
1*e*. Ambulacral area, magnified three diameters.
1*f*. Portion of the same, highly magnified.
1*g*. Apical disk, enlarged.
1*h*. Tubercle, enlarged.



1g

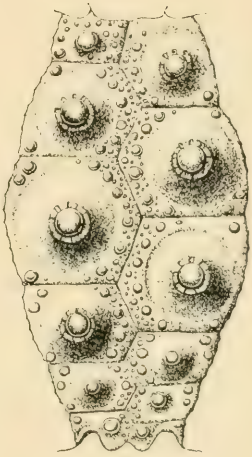


1c



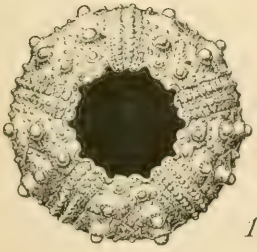
1f

1e

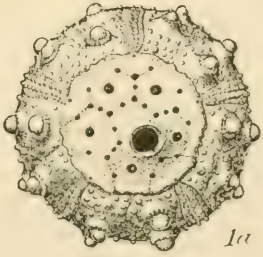


1d

1h



1b



1a

SALENIA.

PLATE XI.

PLATE XI.

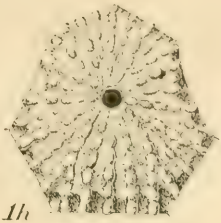
SALENIA TUMIDULA Clark (page 41).

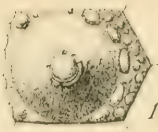
Fig. 1*a*. Upper surface of test, magnified two diameters.
1*b*. Under surface of the same.
1*c*. Lateral surface of the same.
1*d*. Interambulacral area, magnified four diameters.
1*e*. Single plate of same, highly magnified.
1*f*. Ambulacral area, highly magnified.
1*g*. Apical disk, enlarged.
1*h*. Genital plate of same, highly magnified.
1*i*. Mouth opening, enlarged.
1*j*. Tubercle, enlarged.

SALENIA BELLULA Clark (page 43).

Fig. 2*a*. Upper surface of test, magnified two diameters.
2*b*. Under surface of the same.
2*c*. Lateral surface of the same.
2*d*. Three interambulacral plates, highly magnified.
2*e*. Three ambulacral plates, highly magnified.
2*f*. Apical disk, enlarged.
2*g*. Tubercle, highly magnified.

1f


1h

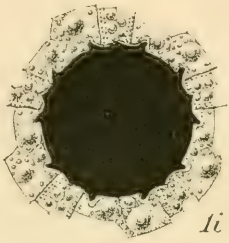

1e

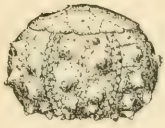
1g

1j

1d

1a

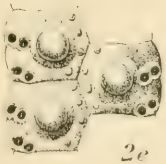

1i


1c

1b

2c

2f


2e

2d

2a

2b

2g

SALENIA.

PLATE XII.

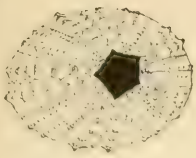
PLATE XII.

HEMICIDARIS INTUMESCENS Clark (page 44).

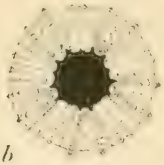
Fig. 1*a*. Upper surface of the test.
1*b*. Lower surface of the test.
1*c*. Lateral view of the same.
1*d*. Two interambulacral plates, highly magnified.
1*e*. Lower portion of interambulacral area, enlarged.
1*f*. Upper portion of same.
1*g*. Portion of ambulacral area, magnified.
1*h*. Tubercle, from above.
1*i*. Lateral view of the same.

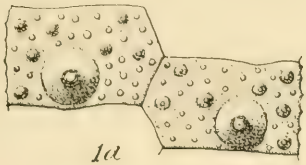
PSEUDODIADEMA EMERSONI Clark (page 45.

Fig. 2*a*. Lateral view of the test.
2*b*. Portion of the interambulacral area, enlarged.
2*c*. Portion of the ambulacral area, enlarged.
2*d*. Tubercle, from the side.
2*e*. The same, from above.


1a

1c


1b


1d

1e

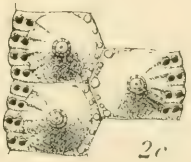
1f

1h

1g

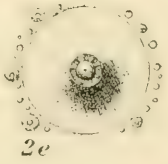
1i

2b


2c

2d

2a


2e

HEMICIDARIS AND PSEUDODIADEMA.

PLATE XIII.

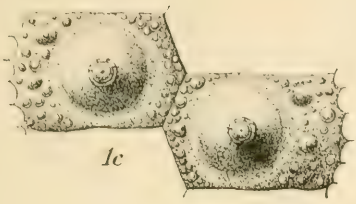
PLATE XIII.

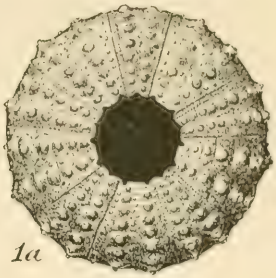
PSEUDODIADEMA DIATRETUM (Morton) (page 46).

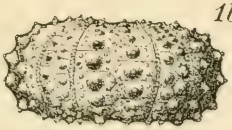
Fig. 1*a*. Under surface of test.
1*b*. Lateral view of the same.
1*c*. Two interambulacral plates, magnified four diameters.
1*d*. Ambulacral plates, highly magnified.
1*e*. Ditto.
1*f*. Tubercle, much enlarged.

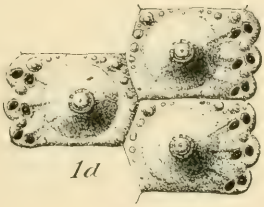
PSEUDODIADEMA TEXANUM (Roemer) (page 47).

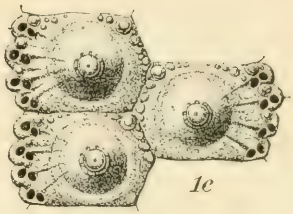
Fig. 2*a*. Upper portion of the interambulacral area, highly magnified.
2*b*. Portion of ambulacral area, ditto.

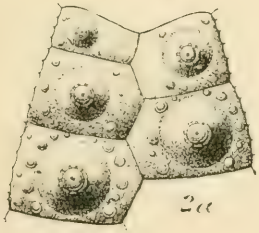


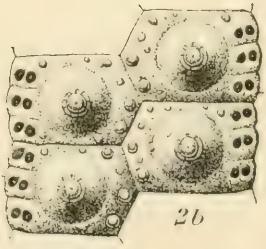












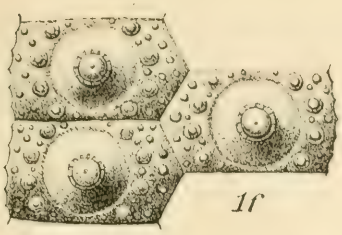
PSEUDODIADEMA.

PLATE XIV

PLATE XIV.

PSEUDODIADEMA TEXANUM (Roemer) (page 47).

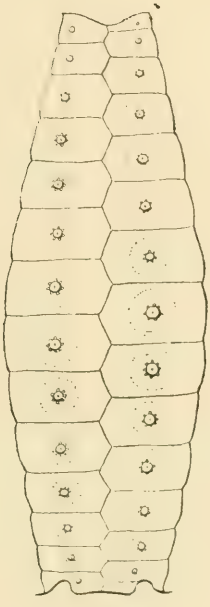
Fig. 1*a*. Upper surface of the test.
1*b*. Lower surface of the same.
1*c*. Lateral surface of the same.
1*d*. Interambulacral area, enlarged.
1*e*. Ambulacral area, enlarged.
1*f*. Three interambulacral plates, highly magnified.
1*g*. Tubercle, much enlarged.



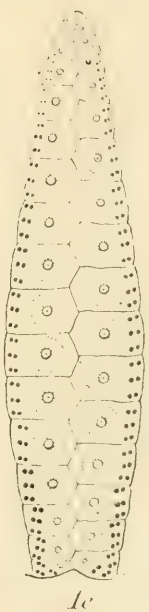
1f

1c

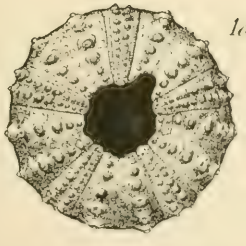
1g



1d



1e



1a

1b

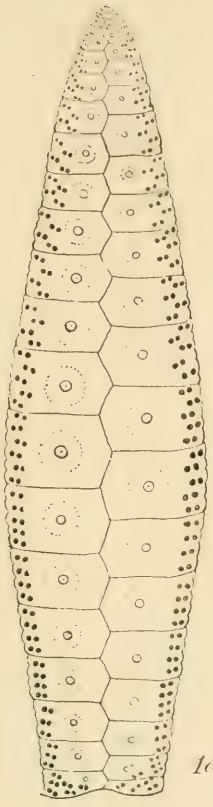
PSEUDODIADEMA.

PLATE XV.

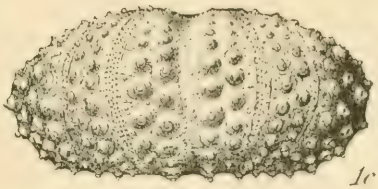
PLATE XV.

DIPLOPODIA TEXANUM (Roemer) (page 48).

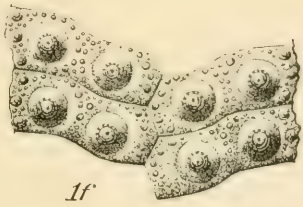
Fig. 1*a*. Upper surface of the test.
1*b*. Lower surface of the same.
1*c*. Lateral surface of the same.
1*d*. Ambulacral area, enlarged.
1*e*. Four plates of the same, highly magnified.
1*f*. Interambulacral plates, ditto.



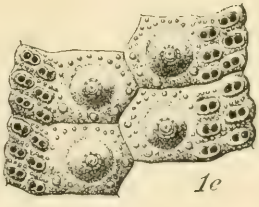
1d



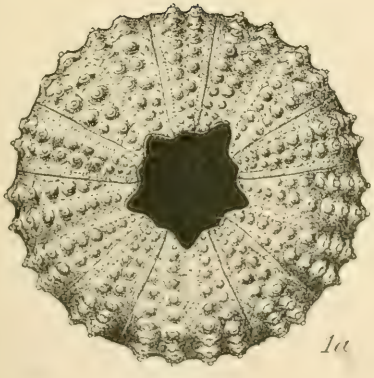
1c



1f



1e



1a

1b

DIPLOPODIA.

PLATE XVI.

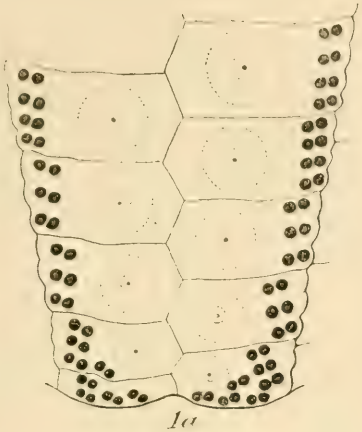
PLATE XVI.

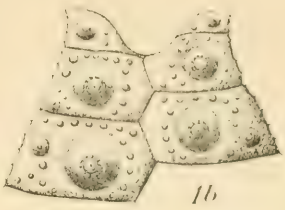
DIPLOPODIA TEXANUM (Roemer) (page 48).

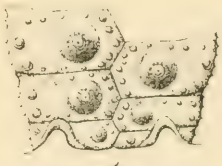
Fig. 1*a*. Lower portion of ambulacral area, highly magnified.
1*b*. Upper portion of interambulacral area, much enlarged.
1*c*. Lower portion of same, ditto.
1*d*. Tubercle.

DIPLOPODIA HILLI Clark (page 50).

Fig. 2*a*. Upper surface of the test.
2*b*. Lower surface of the same.
2*c*. Lateral surface of the same.
2*d*. Upper portion of an ambulacral area, enlarged.
2*e*. Three plates of the same, highly magnified.
2*f*. A portion of an interambulacral area, highly magnified.
2*g*. Tubercle.


1a


1b


1c

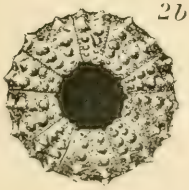
1d

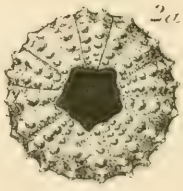
2e

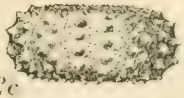
2d

2f

2g


2b


2a


2c

DIPLOPODIA.

PLATE XVII.

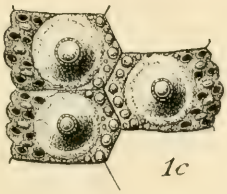
PLATE XVII.

COPTOSOMA MORTONI (de Loriol) (page 51).

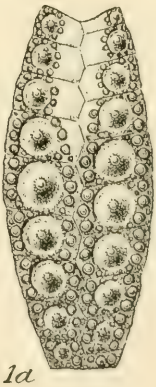
Fig. 1*a*. Upper surface of the test.
1*b*. Lateral view of the same.
1*c*. Three ambulacral plates, much enlarged.
1*d*. Interambulacral area, enlarged.
1*e*. Three interambulacral plates, much enlarged.

1b

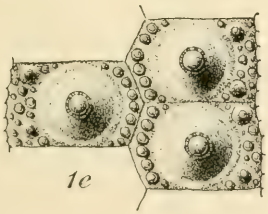
1a



1c



1d



1e

COPTOSOMA.

PLATE XVIII.

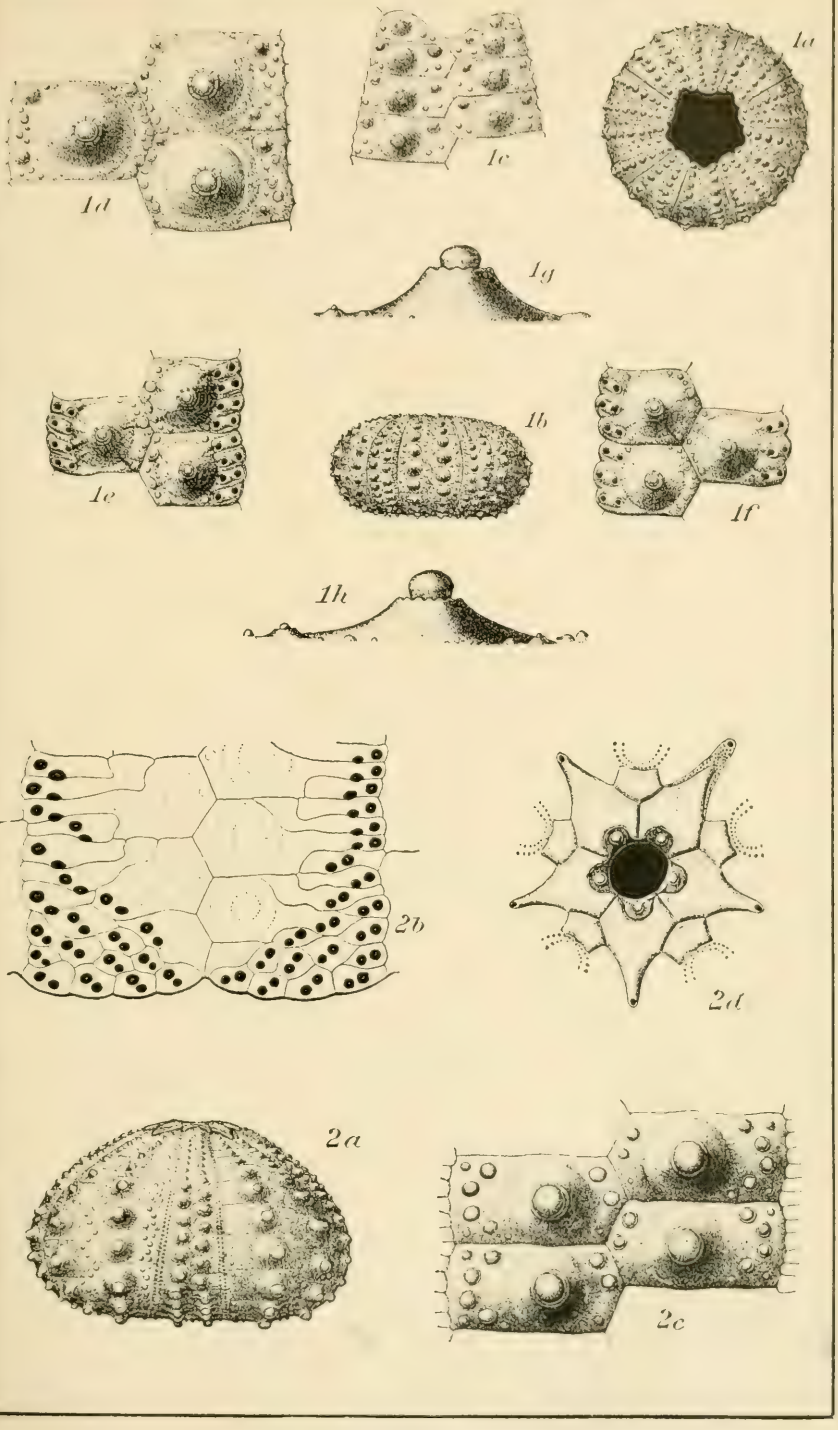
PLATE XVIII.

Coptosoma speciosum Clark (page 52).

Fig. 1*a*. Upper surface of the test.
1*b*. Lateral view of the same.
1*c*. Upper portion of an interambulacral area, enlarged.
1*d*. Three plates of the same, highly magnified.
1*e*. Portion of ambulacral area, highly magnified.
1*f*. Ditto.
1*g*. Tubercle of ambulacral area.
1*h*. Tubercle of interambulacral area.

Goniopygus Zitteli Clark (page 53).

Fig. 2*a*. Lateral surface of the test.
2*b*. Lower portion of ambulacral area, highly magnified.
2*c*. Portion of interambulacral area, highly magnified.
2*d*. Apical disk, enlarged.



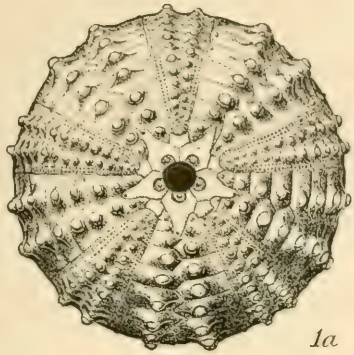
COPTOSOMA AND GONIOPYGUS.

PLATE XIX.

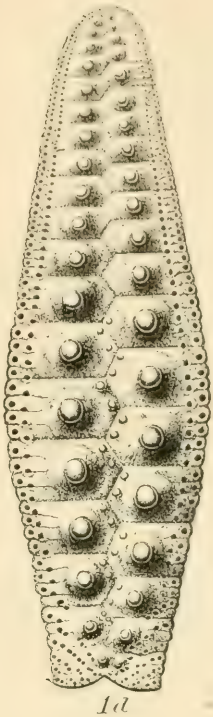
PLATE XIX.

GONIOPYGUS ZITTELI Clark (page 53)

Fig. 1*a*. Upper surface of the test.
1*b*. Lower surface of the same.
1*c*. Interambulacral area, enlarged.
1*d*. Ambulacral area, enlarged.
1*e*. Tubercle.

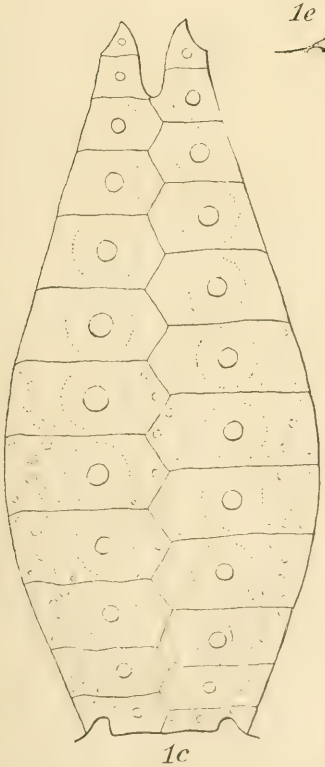


1a

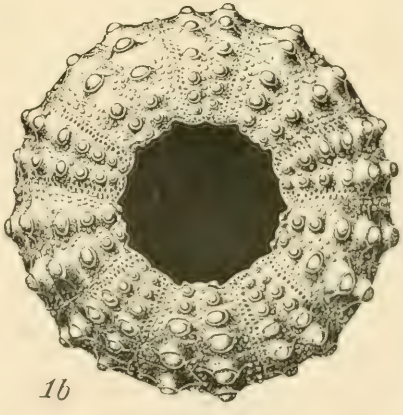


1d

1e



1c



1b

GONIOPYGUS.

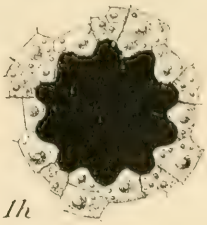
PLATE XX.

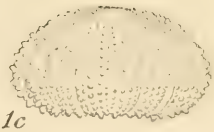
PLATE XX.

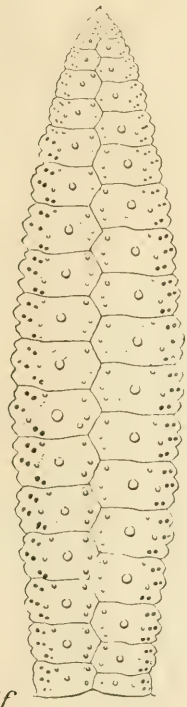
PSAMMECHINUS CINGULATUS Clark (page 55).

Fig. 1*a*. Upper surface of the test.
1*b*. Lower surface of the test.
1*c*. Lateral view of the same.
1*d*. Interambulacral area, enlarged.
1*e*. Three plates of the same, highly magnified.
1*f*. Ambulacral area, enlarged.
1*g*. Four plates of the same, highly magnified.
1*h*. Mouth opening, enlarged.
1*i*. Tubercle.

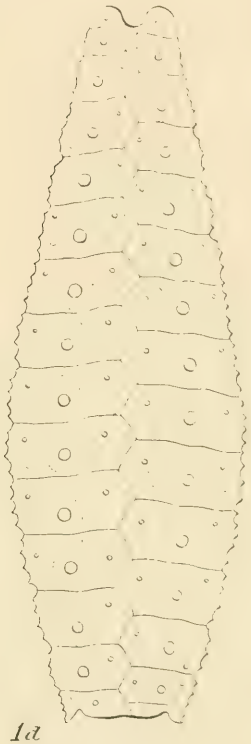
1i


1h

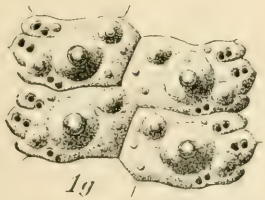

1c

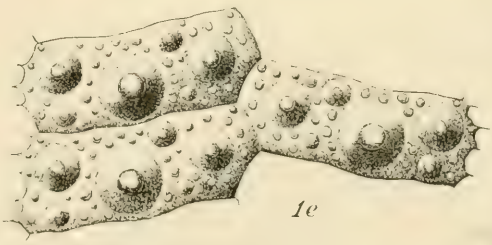

1f

1b


1d

1a


1g


1e

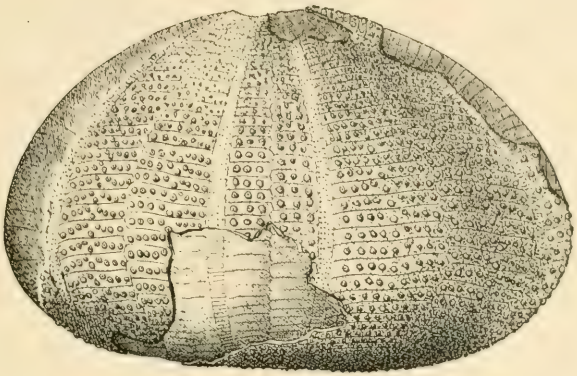
PSAMMECHINUS.

PLATE XXI.

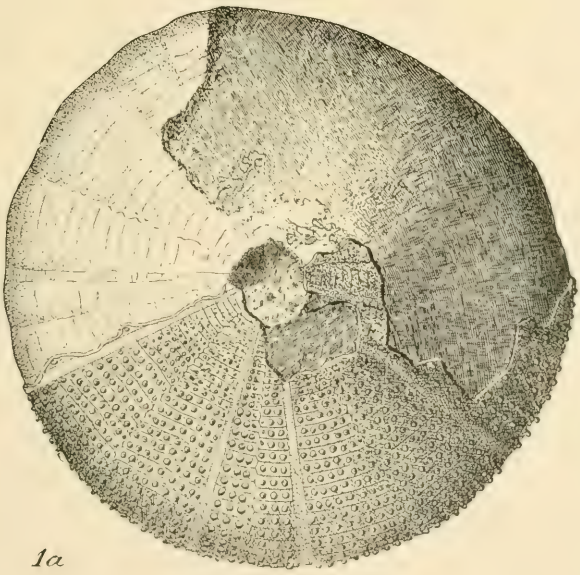
PLATE XXI.

PEDINOPSIS PONDI Clark (page 57).

Fig. 1*a*. Upper surface of the test.
1*b*. Lateral view of the same.



1b



1a

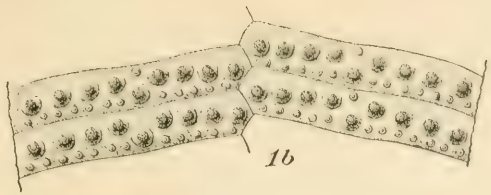
PEDINOPSIS.

PLATE XXII.

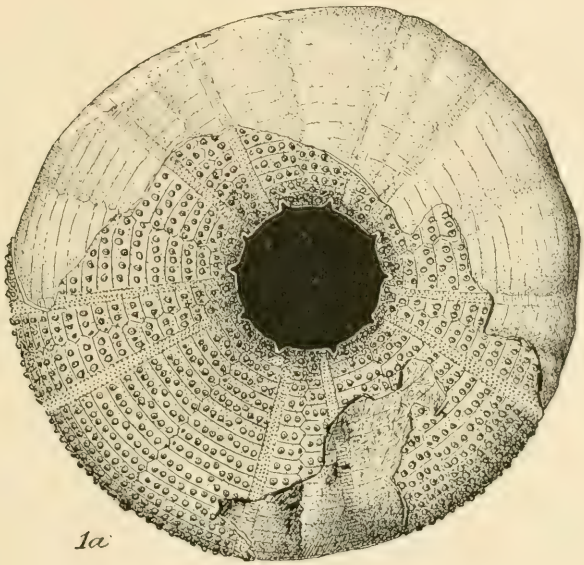
PLATE XXII.

PEDINOPSIS PONDI Clark (page 57).

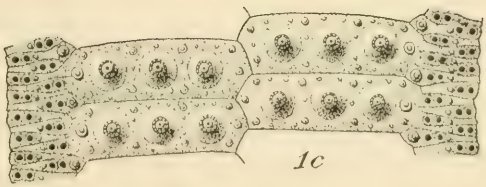
Fig. 1*a*. Lower surface of the test.
1*b*. Four interambulacral plates, much enlarged.
1*c*. Four ambulacral plates, highly magnified.



1b



1a



1c

PEDINOPSIS.

PLATE XXIII.

PLATE XXIII.

STOMECHINUS HYATTI Clark (page 56).

Fig. 1*a*. Lateral surface view of the test, slightly distorted.
1*b*. Portion of the ambulacral area, enlarged.
1*c*. Portion of the interambulacral area, enlarged.
1*d*. Tubercle from above, highly magnified.
1*e*. The same from the side.

HOLECTYPUS PLANATUS Roemer (page 58).

Fig. 2*a*. Upper surface of the test.
2*b*. Lower surface of the same.
2*c*. Lateral surface of the same.
2*d*. Two interambulacral plates, enlarged.
2*e*. Portion of the ambulacral area, highly magnified.
2*f*. Apical disk, enlarged.

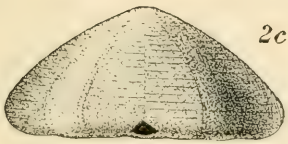
1c

1a

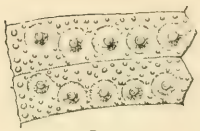
1b

1e

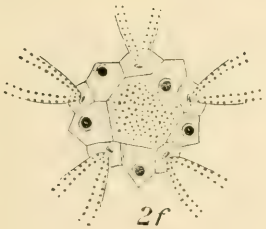
1d



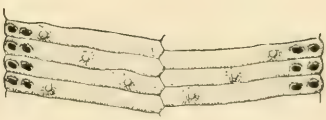
2c



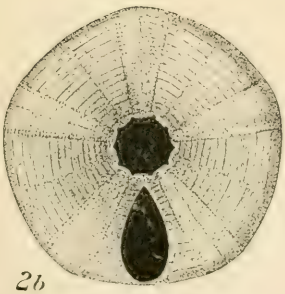
2 d



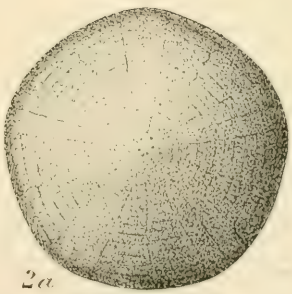
2f



2e



2b



2a

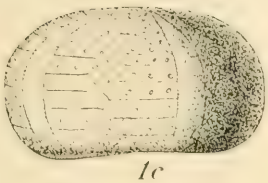
STOMECHINUS AND HOLECTYPUS.

PLATE XXIV.

PLATE XXIV.

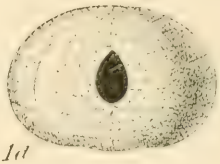
PYRINA PARRYI Hall (page 59).

Fig. 1*a*. Upper surface of the test.
1*b*. Lower surface of the same.
1*c*. Side view of the same.
1*d*. Posterior view of the same.
1*e*. Portion of an ambulacral area, enlarged.
1*f*. The same further enlarged.
1*g*. Two interambulacral plates, magnified three diameters.
1*h*. Portion of single interambulacral plate, highly magnified.
1*i*. Apical disk, enlarged.
1*k*. Portion of the madreporite, highly magnified.

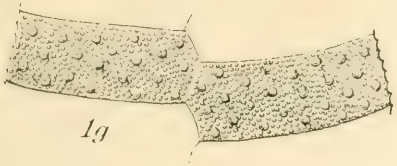


1c

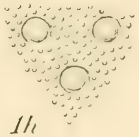
1e



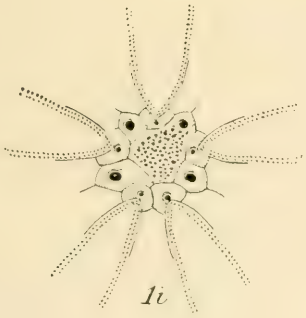
1d



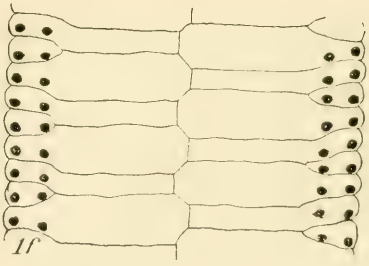
1g



1h

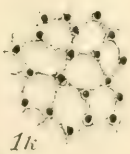


1i



1f

1a



1k

1b

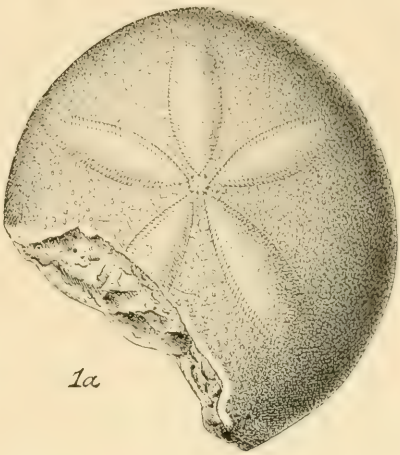
PLATE XXV.

PLATE XXV.

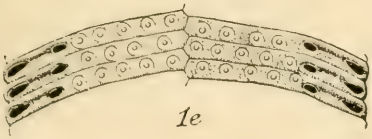
BOTRIOPYGUS ALABAMENSIS Clark (page 60).

Fig. 1*a*. Upper surface of test.
1*b*. Lower surface of test.
1*c*. Side view of the same.
1*d*. Portion of an ambulacral area at base of petaloidal region, enlarged.
1*e*. Same in center of petaloidal region, highly magnified.
1*f*. An interambulacral plate, highly magnified.

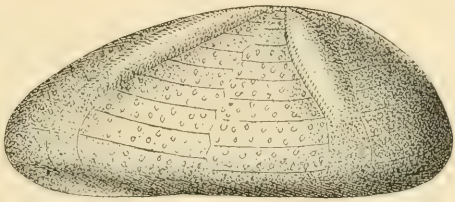
1f



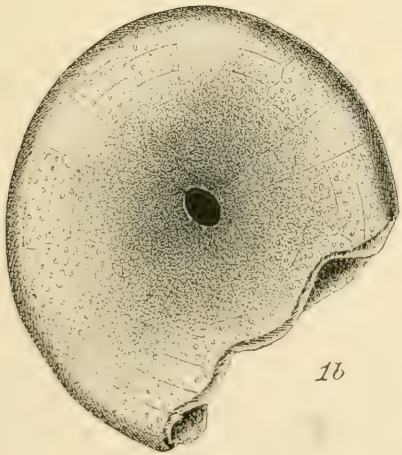
1a



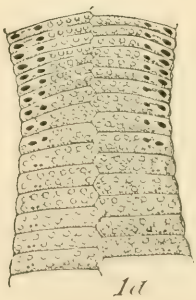
1e



1c



1b



1d

BOTRIOPYGUS.

PLATE XXVI.

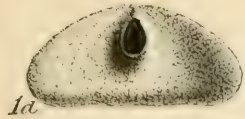
PLATE XXVI.

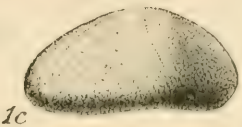
ECHINOBRISSUS EXPANSUS Clark (page 61).

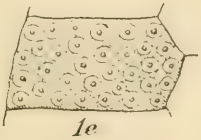
Fig. 1*a*. Upper surface of the test.
1*b*. Lower surface of the test.
1*c*. Side view of the same.
1*d*. Posterior view, showing anal sulcus.
1*e*. An interambulacral plate, enlarged.
1*f*. Portion of the petaloidal region of the right antero-lateral ambulacral area.
1*g*. Apical disk, enlarged.

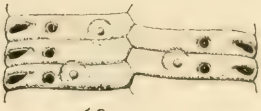
ECHINOBRISSUS TEXANUS Clark (page 62).

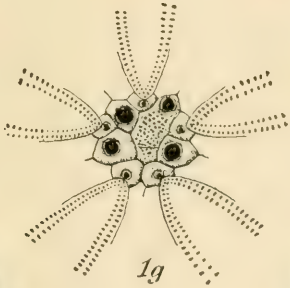
Fig. 2*a*. Upper surface of the test.
2*b*. Lower surface of the test.
2*c*. Side view of the same.
2*d*. Posterior view, showing anal sulcus.
2*e*. Portion of the right antero-lateral ambulacrum.
2*f*. Four interambulacral plates, highly magnified.

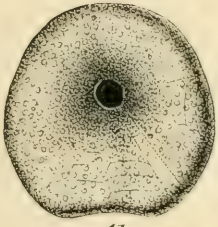

1d

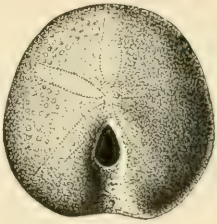

1c


1e


1f

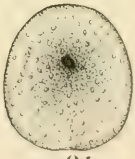

1g


1b


1a

2c

2a


2b

2d

2e

2f

ECHINOBRISSUS.

PLATE XXVII.

PLATE XXVII.

TREMATOPYGUS CRUCIFER (Morton) (page 63).

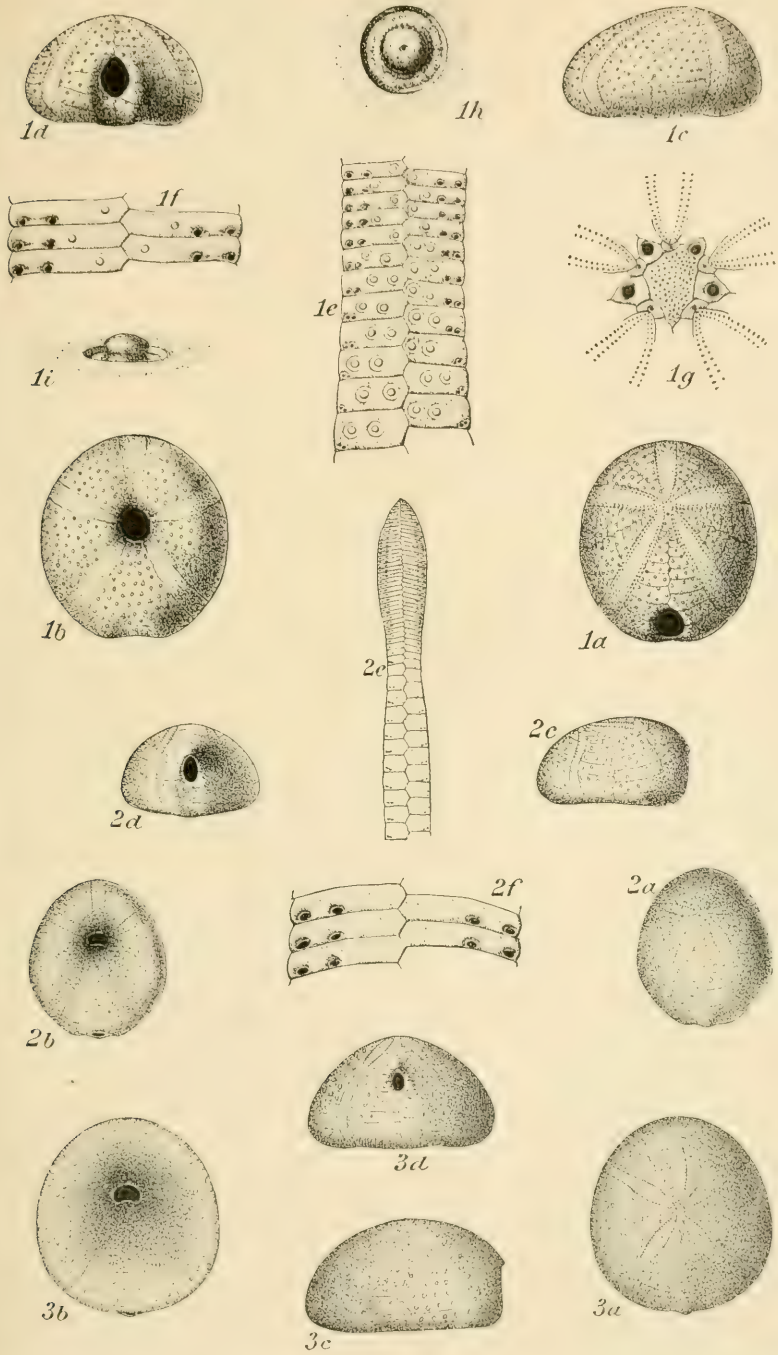
Fig. 1*a*. Upper surface of the test.
1*b*. Lower surface of the test.
1*c*. Side view of the same.
1*d*. Posterior view of the same.
1*e*. Lower portion of the petaloidal region of the right postero-lateral ambulacrum.
1*f*. Much enlarged view of several plates of the same.
1*g*. Apical disk, enlarged.
1*h*. Tubercle from above.
1*i*. Lateral view of the same.

CATOPYGUS OVIFORMIS Conrad (page 64).

Fig. 2*a*. Upper surface of the test.
2*b*. Lower surface of the test.
2*c*. Lateral view of the same.
2*d*. Posterior view of the same.
2*e*. Right postero-lateral ambulacrum, enlarged.
2*f*. Several plates of the same, highly magnified.

CATOPYGUS PUSILLUS Clark (page 65).

Fig. 3*a*. Upper surface of the test.
3*b*. Lower surface of the test.
3*c*. Lateral view of the same.
3*d*. Posterior view of the same.



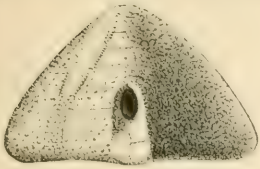
TREMATOPYGUS AND CATOPYGUS.

PLATE XXVIII.

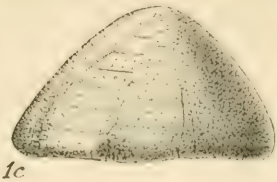
PLATE XXVIII.

CASSIDULUS FLOREALIS (Morton) (page 66).

Fig. 1*a*. Upper surface of the test.
1*b*. Lower surface of the test.
1*c*. Lateral view of the same.
1*d*. Posterior view of the same.
1*e*. Right postero-lateral ambulacrum.
1*f*. Several plates in the petaloidal region of the same, much enlarged.
1*g*. Ditto, lower surface.
1*h*. Posterior interambulacrum.
1*i*. Single plate, much enlarged.
1*j*. Apical disk, highly magnified.
1*k*. Tubercle from above.
1*l*. Lateral view of the same.

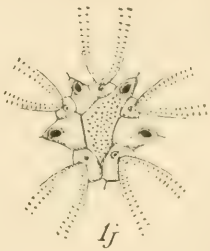

1d

1b


1c

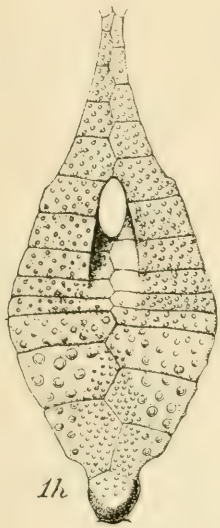
1i

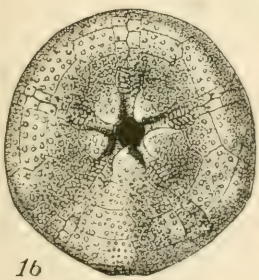
1e

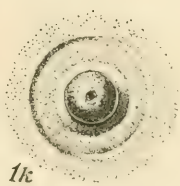

1f

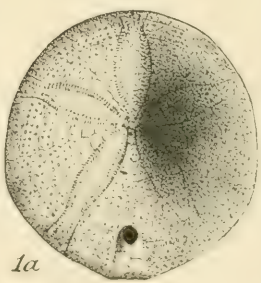
1f

1g


1h


1b


1k


1a

CASSIDULUS.

PLATE XXIX.

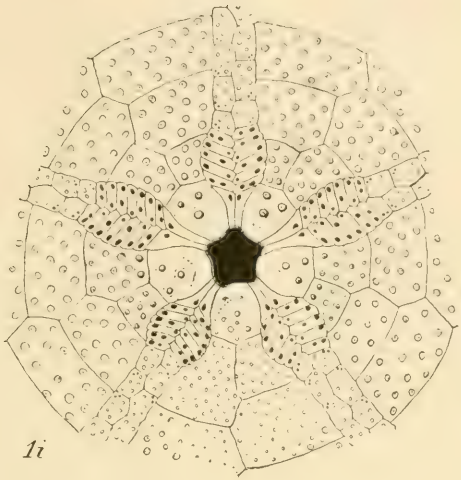
PLATE XXIX.

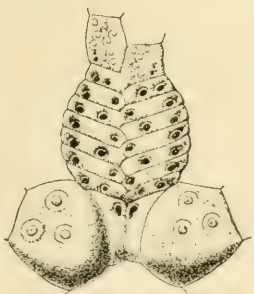
CASSIDULUS ÆQUOREUS Morton (page 68).

Fig. 1*a*. Upper surface of the test.
1*b*. Lower surface of the test.
1*c*. Lateral view of the same.
1*d*. Posterior view of the same.
1*e*. Anterior ambulacrum.
1*f*. Several plates, petaloidal region of the same, much enlarged.
1*g*. Ditto, oral region.
1*h*. Apical disk, much enlarged.
1*i*. Diagram showing the arrangement of the plates about the peristomial opening.

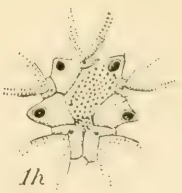
1d.

1c.

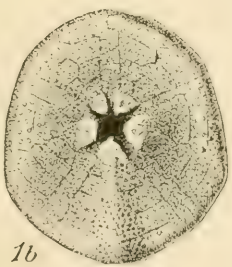

1i.


1g.

1e.


1h.

1f.


1b.

1a.

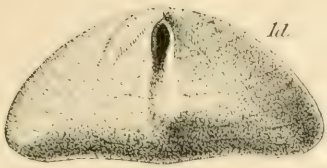
CASSIDULUS.

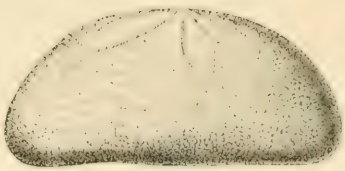
PLATE XXX.

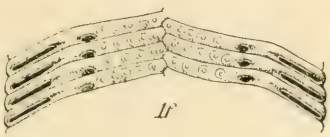
PLATE XXX.

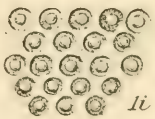
CASSIDULUS MICROCOCCUS Gabb (page 69).

Fig. 1*a*. Upper surface of the test.
1*b*. Lower surface of the test.
1*c*. Lateral view of the same.
1*d*. Posterior view of the same.
1*e*. Anterior ambulacrum at the base of the petaloidal region.
1*f*. Several plates in petaloidal region of anterior ambulacrum, much enlarged.
1*g*. Oral portion of an ambulacral area.
1*h*. Apical disk, enlarged.
1*i*. Surface of an interambulacral plate, highly magnified.

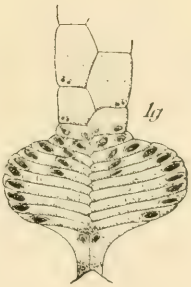

1d

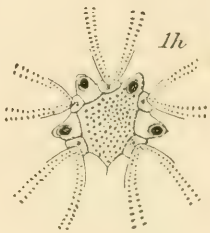

1c

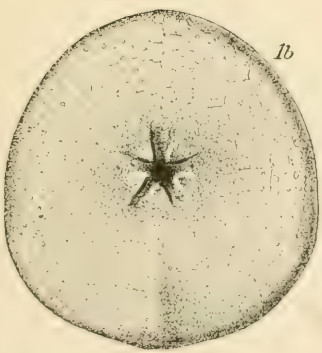

1f

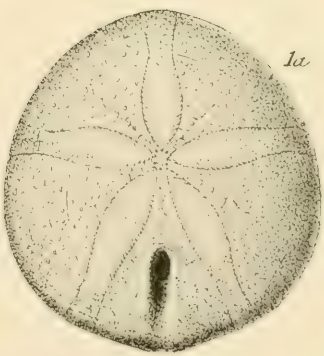

1i

1e


1g


1h


1b


1a

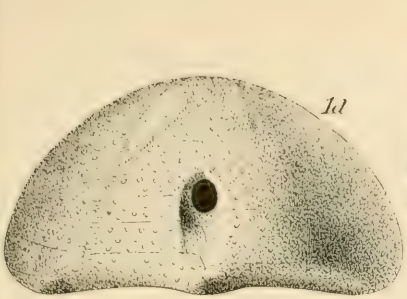
CASSIDULUS.

PLATE XXXI.

PLATE XXXI.

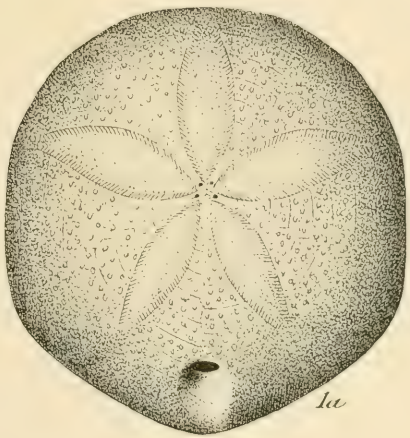
CASSIDULUS SUBQUADRATUS Conrad (page 70).

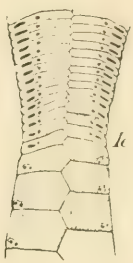
Fig. 1*a*. Upper surface of the test.
1*b*. Lower surface of the test.
1*c*. Lateral view of the same.
1*d*. Posterior view of the same.
1*e*. Lower portion of the petaloidal region of the right antero-lateral ambulacrum.
1*f*. Several plates of the same, much enlarged.
1*g*. Oral portion, much enlarged.
1*h*. Apical disk, enlarged.

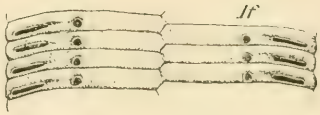

1d

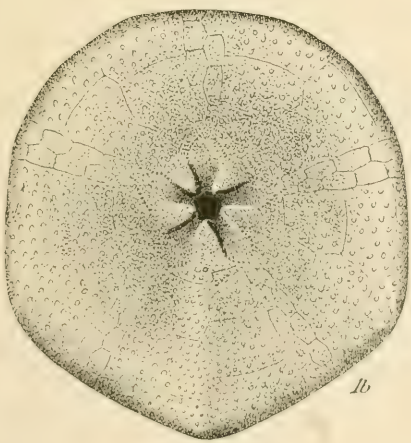
1c

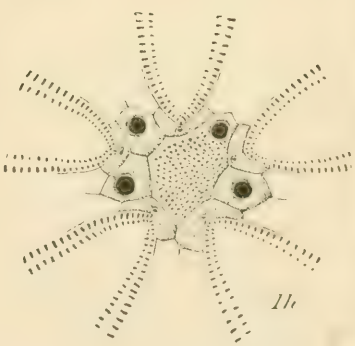
1g


1a


1e


1f


1b


1h

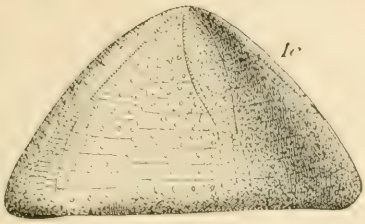
CASSIDULUS.

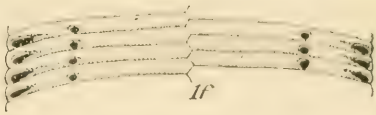
PLATE XXXII.

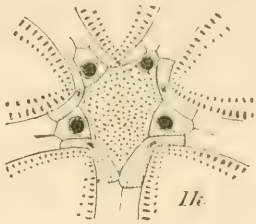
PLATE XXXII.

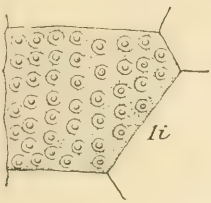
CASSIDULUS SUBCONICUS Clark (page 71).

Fig. 1*a*. Upper surface of the test.
1*b*. Lower surface of the test.
1*c*. Lateral view of the same.
1*d*. Posterior view of the same.
1*e*. An ambulacral area, enlarged.
1*f*. Several plates of the petaloidal portion, highly magnified.
1*g*. Ditto, oral portion.
1*h*. Diagram showing the arrangement of the plates around peristomial opening.
1*i*. Interambulacral plate, much enlarged.
1*k*. Apical disk, much enlarged.

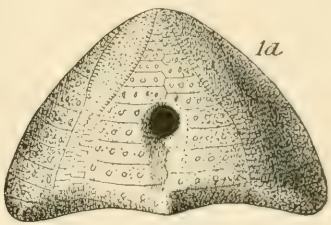

1c

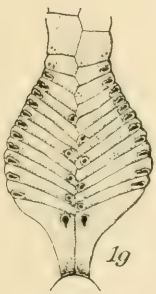

1f

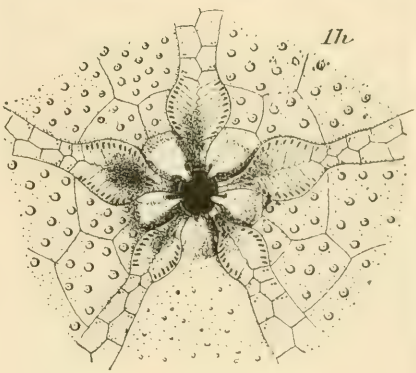

1h

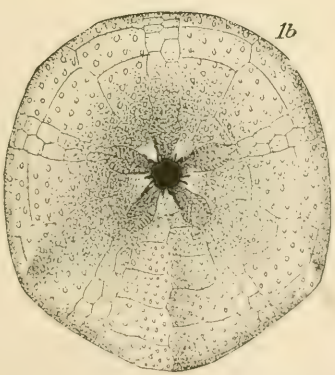

1i

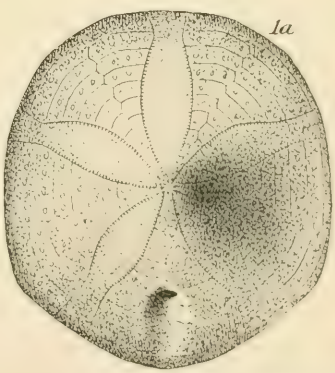
1e


1a


1g


1h


1b


1a

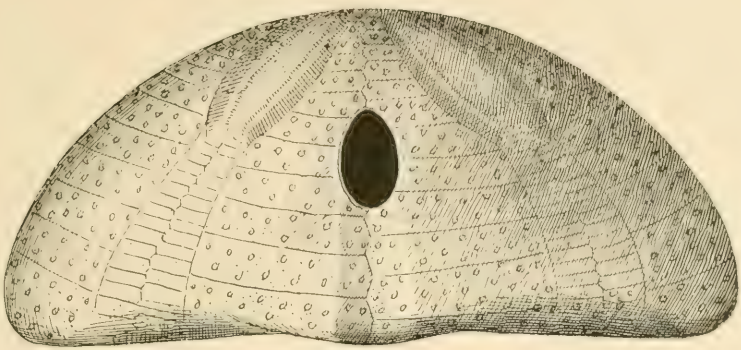
CASSIDULUS.

PLATE XXXIII.

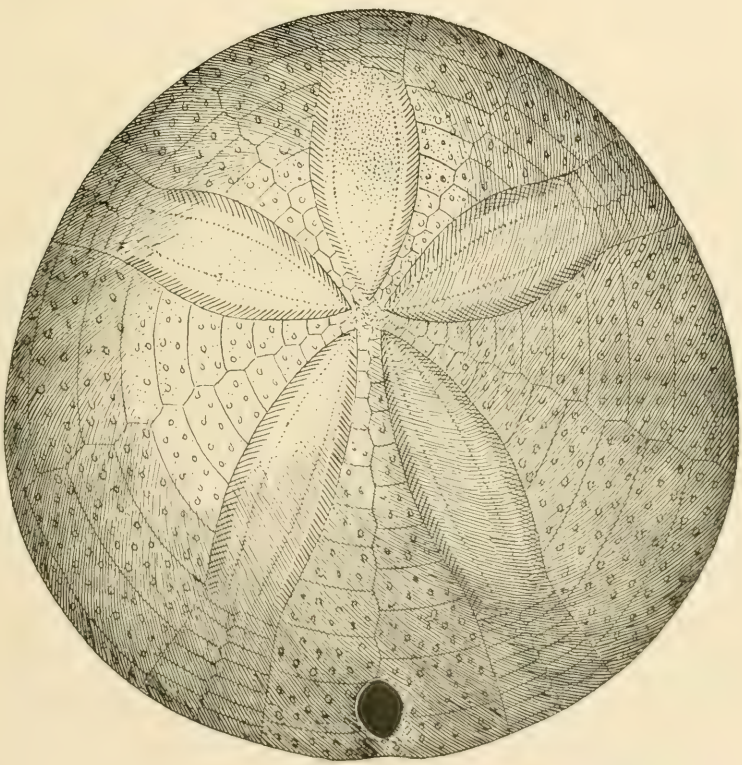
PLATE XXXIII.

CASSIDULUS PORRECTUS Clark (page 72).

Fig. 1*a*. Upper surface of the test.
1*b*. Posterior view of the same.



1b



1a

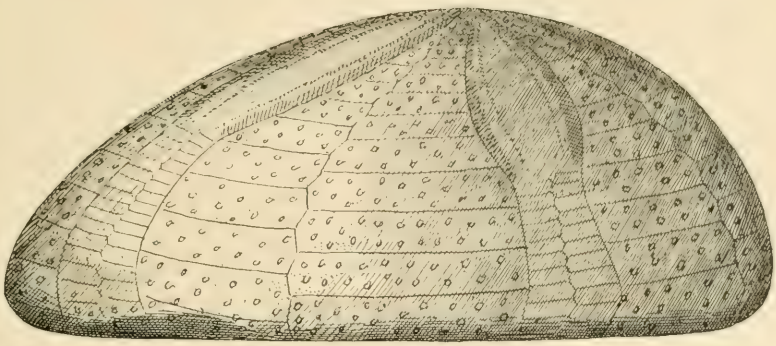
CASSIDULUS.

PLATE XXXIV.

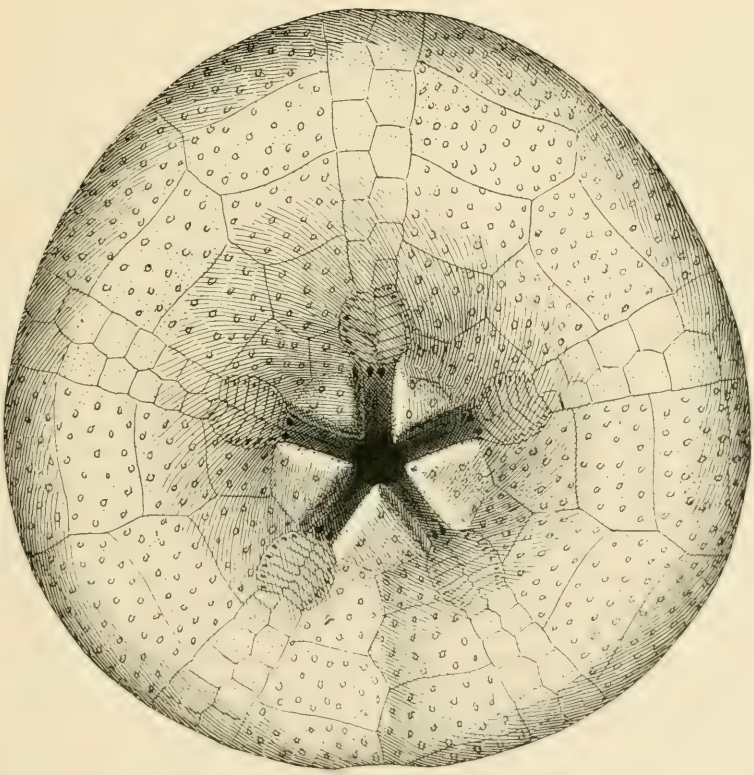
PLATE XXXIV.

CASSIDULUS PORRECTUS Clark (page 72).

Fig. 1*a*. Lower surface of the test.
1*b*. Lateral view of the same.



1b



1a

CASSIDULUS.

PLATE XXXV.

PLATE XXXV.

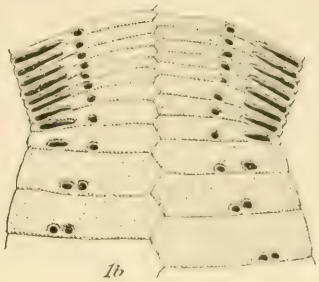
CASSIDULUS RORRECTUS Clark (page 72).

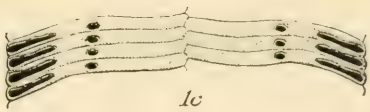
Fig. 1*a*. An ambulacral area, enlarged.
1*b*. Lower portion of petaloidal region, highly magnified.
1*c*. Central portion of same, highly magnified.
1*d*. Three interambulacral plates, much enlarged.

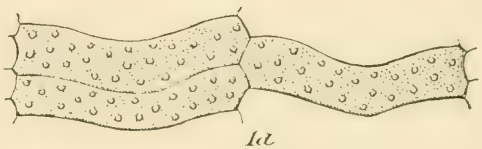
CASSIDULUS STANTONI Clark (page 73).

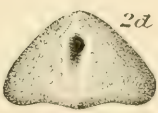
Fig. 2*a*. Upper surface of the test.
2*b*. Lower surface of the test.
2*c*. Lateral view of the same.
2*d*. Posterior view of the same.

1a


1b

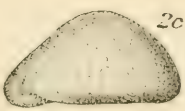

1c


1d


2d

2b

2a


2c

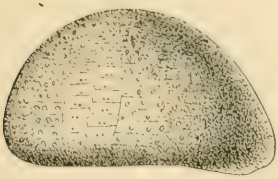
CASSIDULUS.

PLATE XXXVI.

PLATE XXXVI.

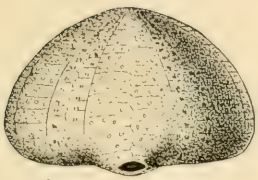
ANANCHYTES OVALIS Clark (page 74).

Fig. 1*a*. Upper surface of the test.
1*b*. Lower surface of the same.
1*c*. Lateral view of the same.
1*d*. Anterior view of the same.
1*e*. Posterior view of the same.
1*f*. Apical disk, enlarged.
1*g*. Ambulacral plates, much enlarged.
1*h*. Interambulacral plates, much enlarged.

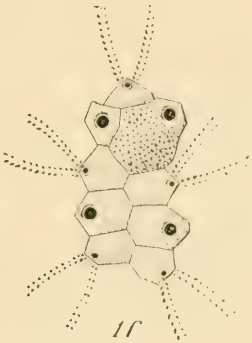


1c

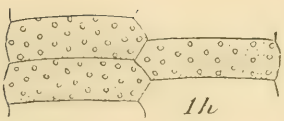
1d



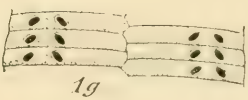
1e



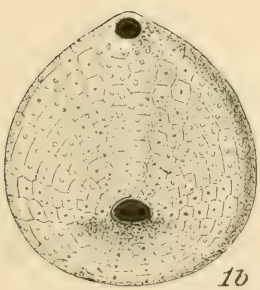
1f



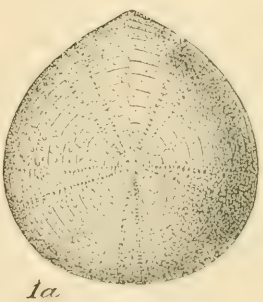
1h



1g



1b



1a

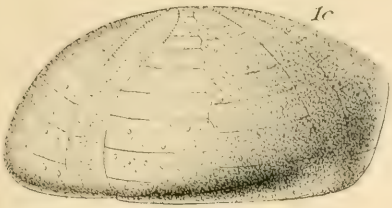
ANANCHYTES.

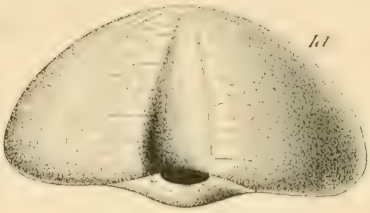
PLATE XXXVII.

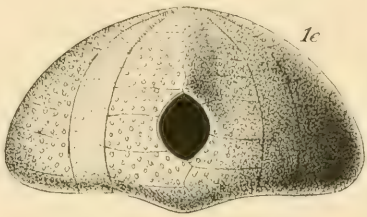
PLATE XXXVII.

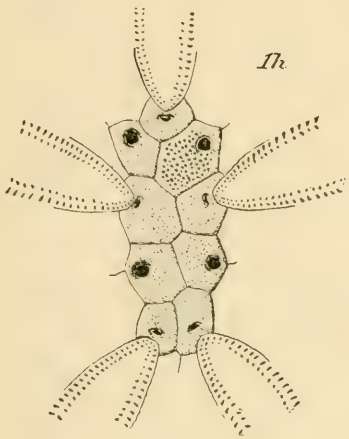
CARDIASTER CINCTUS (Morton) (page 75).

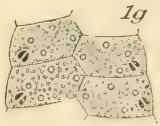
Fig. 1*a*. Upper surface of the test.
1*b*. Lower surface of the test.
1*c*. Lateral view of the same.
1*d*. Anterior view of the same.
1*e*. Posterior view of the same.
1*f*. Central portion of the petaloidal region of an ambulacral area, much enlarged.
1*g*. Basal portion, ditto.
1*h*. Apical disk, enlarged.

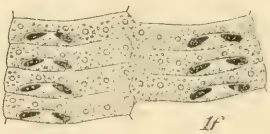

1c

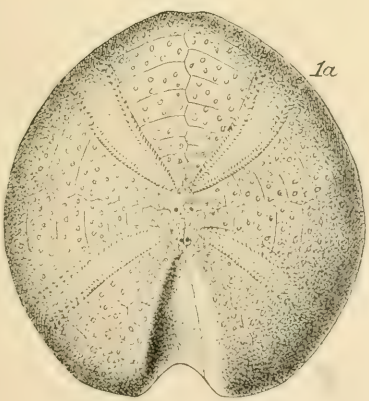

1d

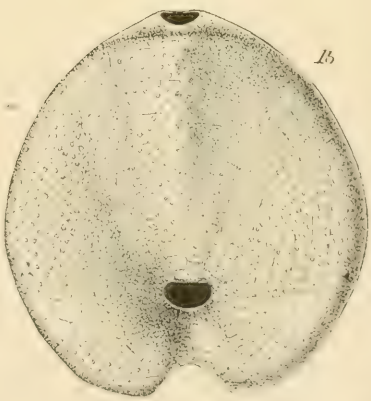

1e


1h


1g


1f


1a


1b

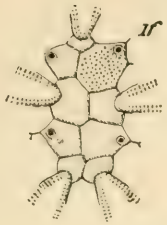
CARDIASTER.

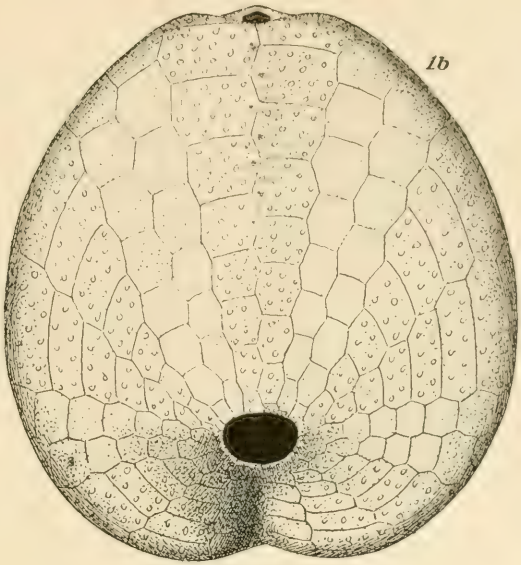
PLATE XXXVIII.

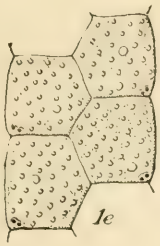
PLATE XXXVIII.

HOLASTER SIMPLEX Shumard (page 76).

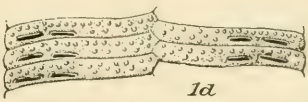
Fig. 1*a*. Upper surface of the test.
1*b*. Lower surface of the same.
1*c*. The right antero-lateral ambulacrum, enlarged.
1*d*. Portion of the petaloidal region of the same.
1*e*. Four basal plates of the same.
1*f*. Apical disk, enlarged.
1*g*. Tubercle, highly magnified.

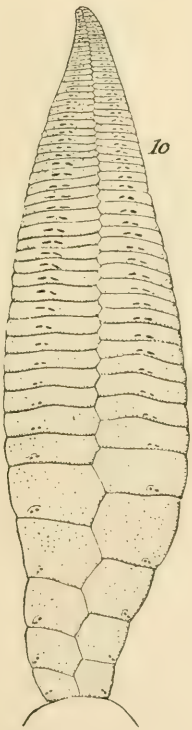

1f

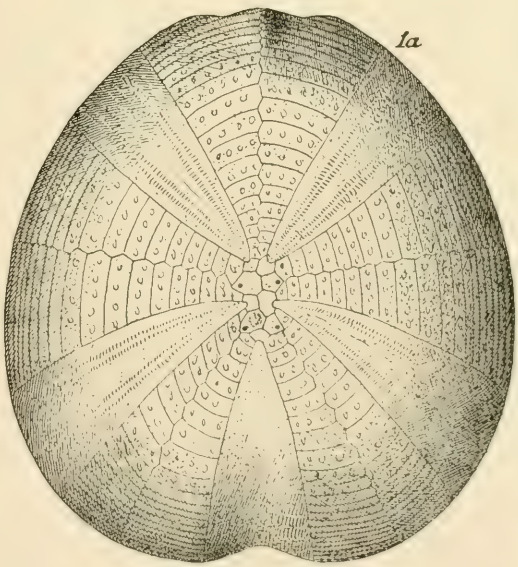

1b


1e

1g


1d


1o


1a

HOLASTER.

PLATE XXXIX.

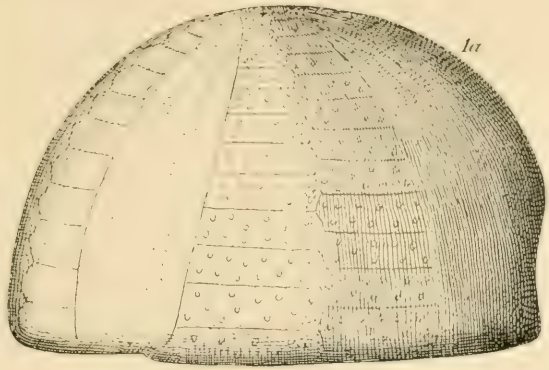
PLATE XXXIX.

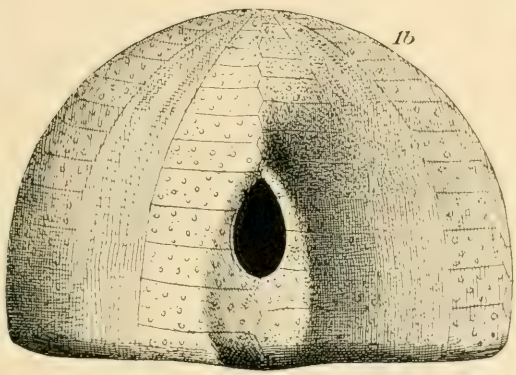
HOLASTER SIMPLEX Shumard (page 76).

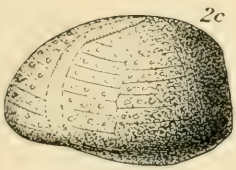
Fig. 1*a*. Lateral view of the test.
1*b*. Posterior view of the same.
1*c*. Interambulacral plate, much enlarged.
1*d*. Tubercle, highly magnified.

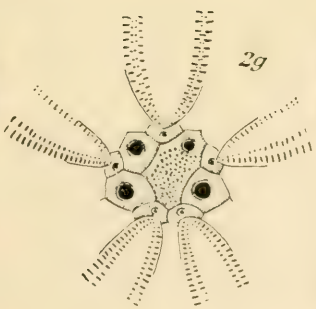
ENALLASTER TEXANUS Roemer (page 78).

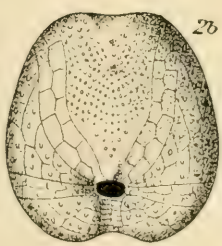
Fig. 2*a*. Upper view of the test.
2*b*. Lower view of the test.
2*c*. Lateral view of the same.
2*d*. Posterior view of the same.
2*e*. Portion of the petaloidal region of the right antero-lateral ambulacrum, much enlarged.
2*f*. Ditto, anterior ambulacrum.
2*g*. Apical disk, enlarged.

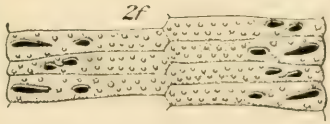


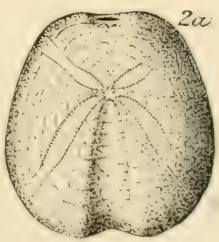












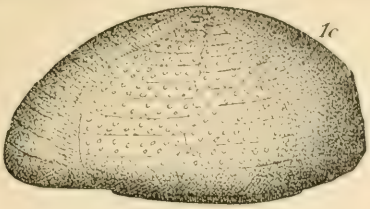
HOLASTER AND ENALLASTER.

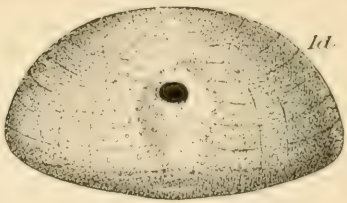
PLATE XL.

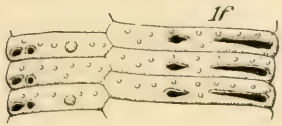
PLATE XL.

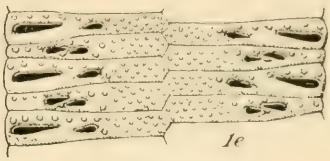
ENALLASTER OBLIQUATUS Clark (page 79).

Fig. 1*a*. Upper surface of the test.
1*b*. Lower surface of the test.
1*c*. Lateral view of the same.
1*d*. Posterior view of the same.
1*e*. Portion of the petaloidal region of the anterior ambulacrum.
1*f*. Ditto, left anterior ambulacrum.
1*g*. Second plate of the same from the mouth opening.
1*h*. Diagram showing arrangement of plates about the mouth opening.
1*i*. Apical disk, enlarged.
1*k*. Tubercle from above, much enlarged.
1*l*. Lateral view of the same.

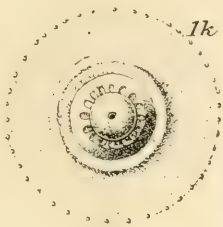

1c

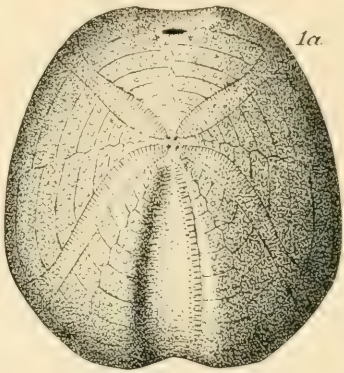

1d

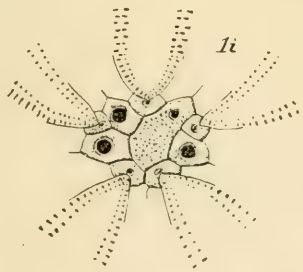

1f


1e

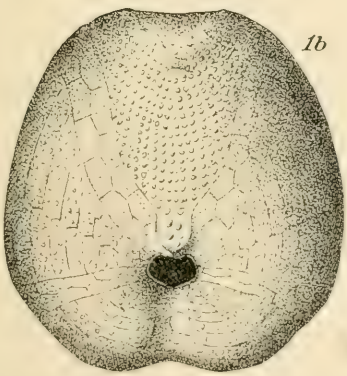
1g

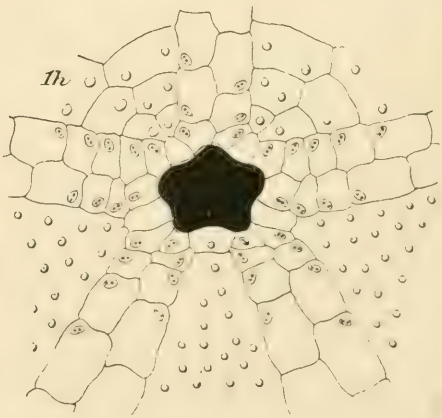

1k


1a


1i

1l


1b


1h

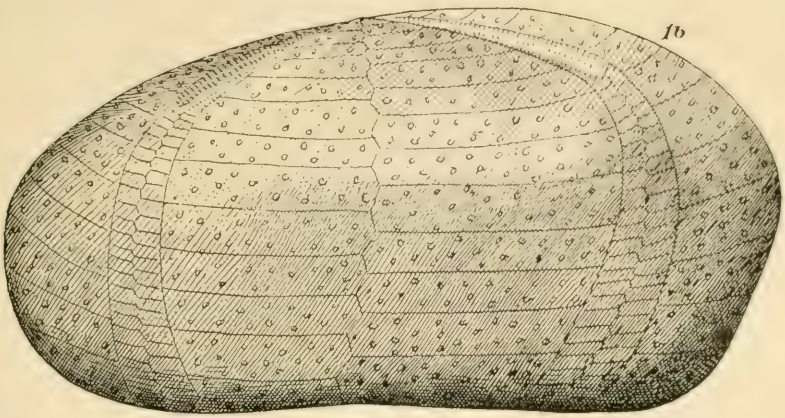
ENALLASTER.

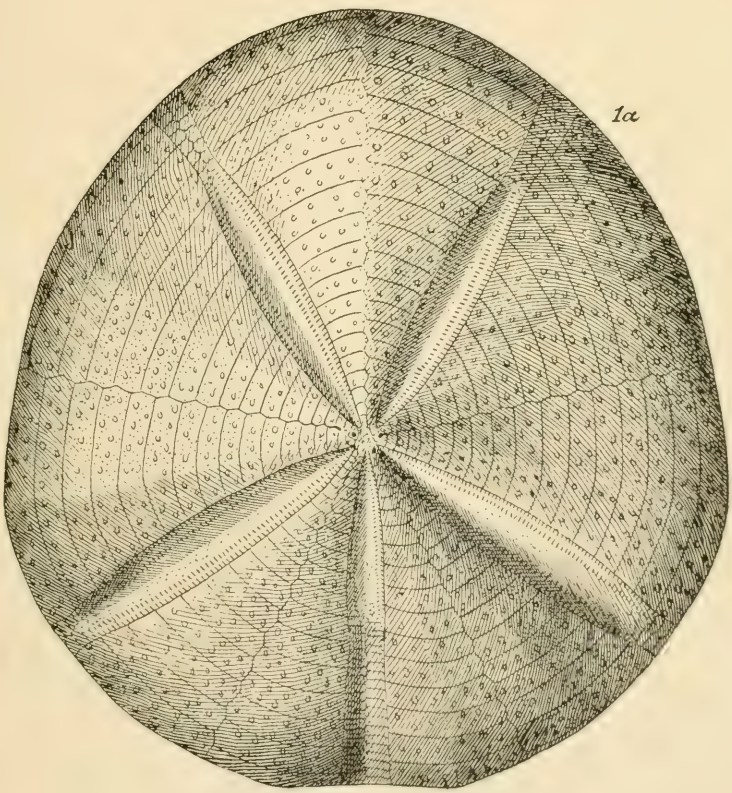
PLATE XLI.

PLATE XLI.

EPIASTER ELEGANS (Shumard) (page 80).

Fig. 1*a*. Upper surface of the test.
1*b*. Lateral view of the same.





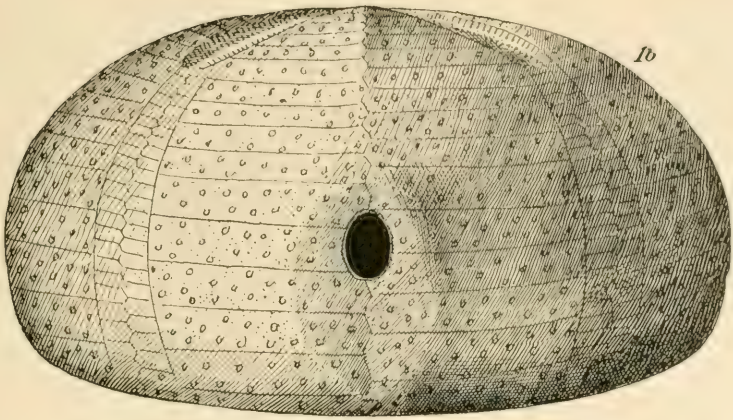
EPIASTER.

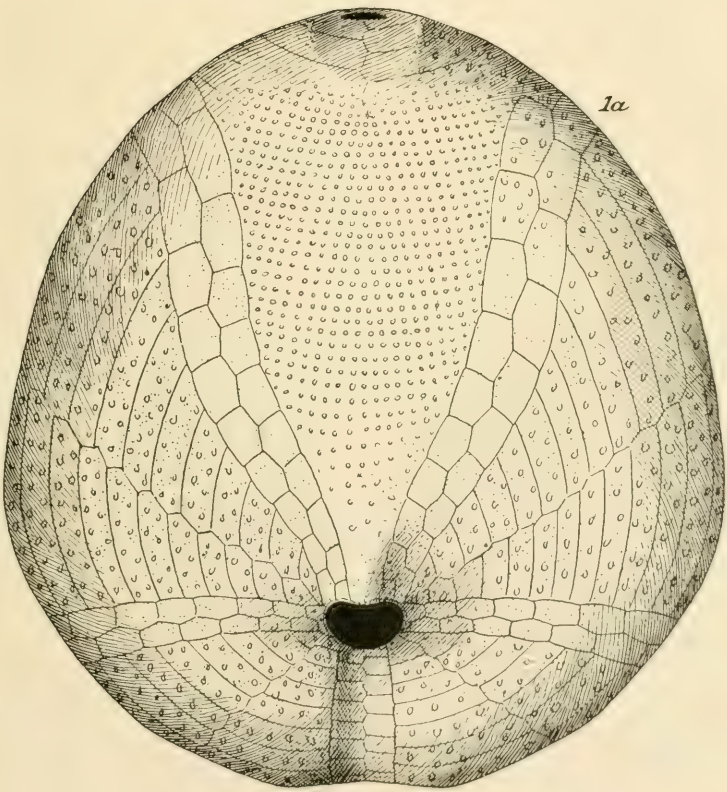
PLATE XLII.

PLATE XLII.

EPIASTER ELEGANS (Shumard) (page 80).

Fig. 1*a*. Lower surface of the test.
1*b*. Posterior view of the same.





EPIASTER.

PLATE XLIII.

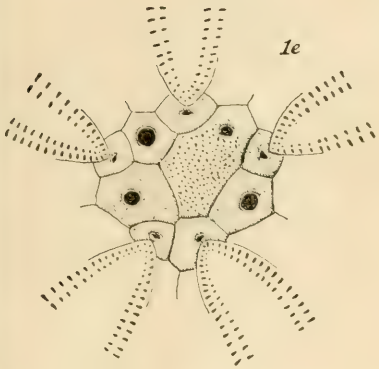
PLATE XLIII.

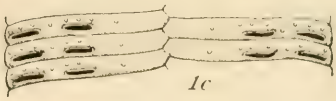
EPIASTER ELEGANS (Shumard) (page 80).

Fig. 1*a*. Upper portion of the anterior ambulacrum, enlarged.
1*b*. Middle portion of the petaloidal region of the anterior ambulacrum, highly magnified.
1*c*. Ditto, left antero-lateral ambulacrum.
1*d*. Two interambulacral plates, much enlarged.
1*e*. Apical disk, enlarged.

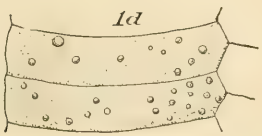
EPIASTER WHITEI Clark (page 82).

Fig. 2*a*. Lateral view of the test.
2*b*. Posterior view of the same.
2*c*. Left antero-lateral ambulacrum, enlarged.
2*d*. Diagram showing the arrangement of the plates in the apical disk and bordering areas.


1e

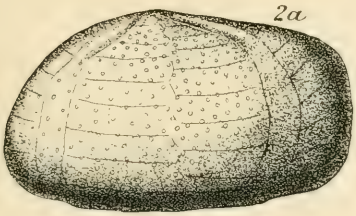

1c

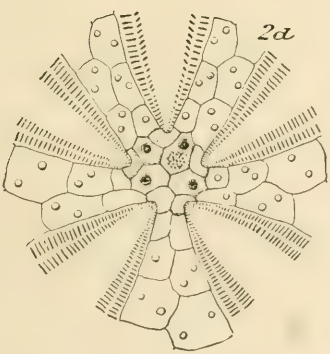
1b

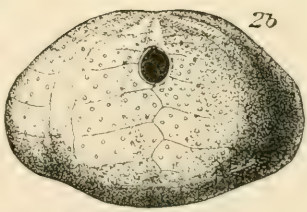

1d

1a

2c


2a


2d


2b

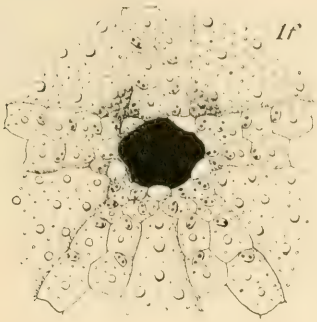
EPIASTER.

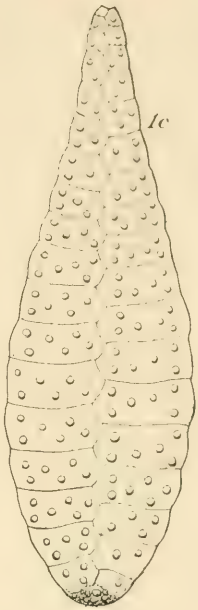
PLATE XLIV.

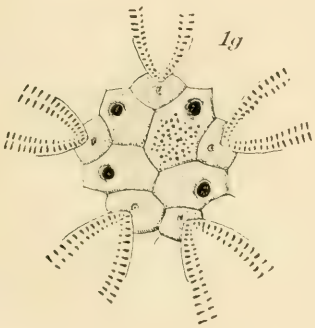
PLATE XLIV.

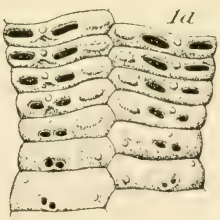
EPIASTER WHITEI Clark (page 82).

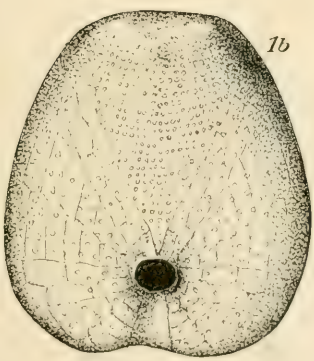
Fig. 1*a*. Upper surface of the test.
1*b*. Lower surface of the same.
1*c*. Right antero-lateral interambulacral area, much enlarged.
1*d*. Lower portion of the petaloidal region of the right antero-lateral ambulacrum, highly magnified.
1*e*. Several plates of the petaloidal region of the left antero-ambulacrum.
1*f*. Peristomial opening, with surrounding ambulacral and interambulacral plates.
1*g*. Apical disk, much enlarged.

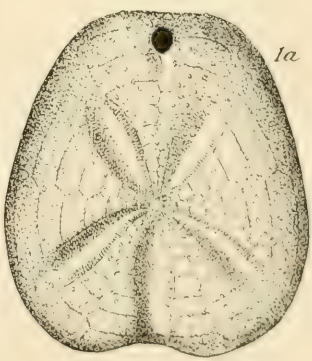












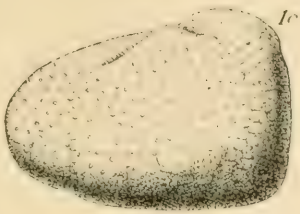
EPIASTER.

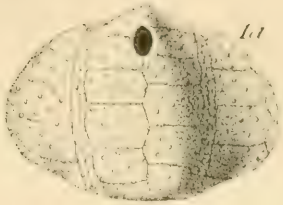
PLATE XLV.

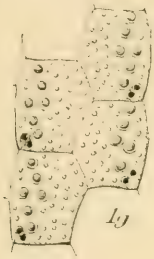
PLATE XLV.

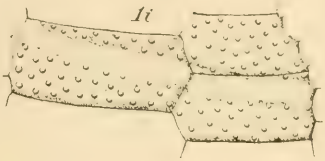
HEMIASTER PARASTATUS (Morton) (page 83).

Fig. 1*a*. Upper surface of the test.
1*b*. Lower surface of the test.
1*c*. Lateral view of the same.
1*d*. Posterior view of the same.
1*e*. Anterior ambulacrum, enlarged.
1*f*. Portion of petaloidal region of the same, highly magnified.
1*g*. Portion of basal region, ditto.
1*h*. Several plates from the petaloidal region of the right antero-lateral ambulacrum, much enlarged.
1*i*. Three interambulacral plates, with fasciole.
1*k*. Portion of fasciole, highly magnified.
1*l*. Tubercle from the side.
1*m*. Ditto from above.
1*n*. Apical disk, enlarged.


1c


1d


1g

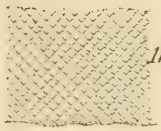

1i

1e

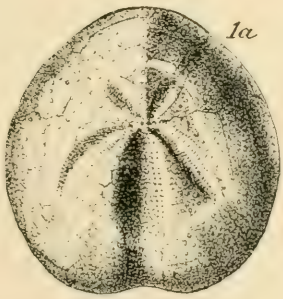
1f

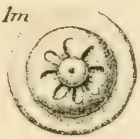
1n

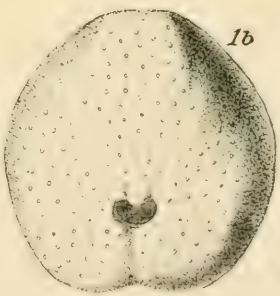
1h


1k

1l


1a


1m


1b

HEMIASTER.

PLATE XLVI.

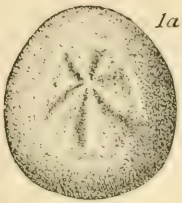
PLATE XLVI.

HEMIASTER STELLA (Morton) (page 84).

Fig. 1*a*. Upper surface of the test.
1*b*. Lower surface of the test.
1*c*. Lateral view of the same.
1*d*. Posterior view of the same.

HEMIASTER UNGULA (Morton) (page 85).

Fig. 2*a*. Upper surface of the test.
2*b*. Lower surface of the test.
2*c*. Lateral view of the same.
2*d*. Posterior view of the same.
2*e*. Portion of the petaloidal region of the right antero-lateral ambulacrum, much enlarged.
2*f*. Ditto, anterior ambulacrum.
2*g*. Apical disk, enlarged.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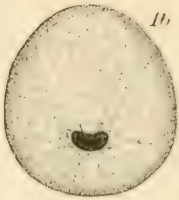
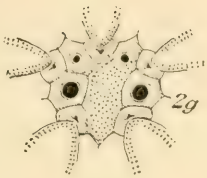
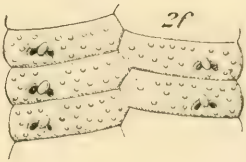
1c


1b

1d


2g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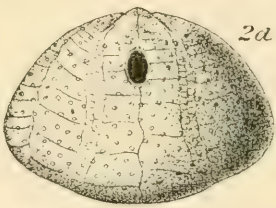
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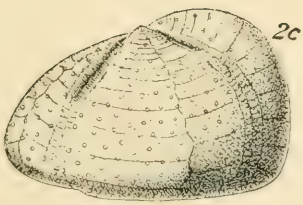
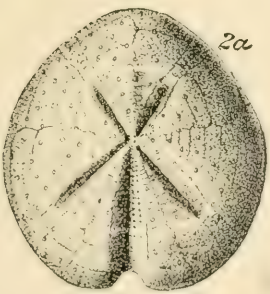

2c

2e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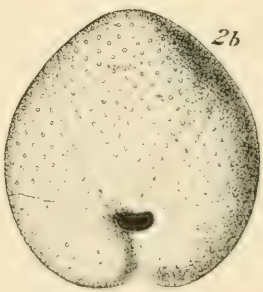

2b

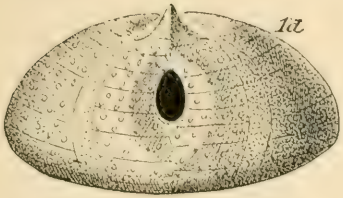
HEMIASTER

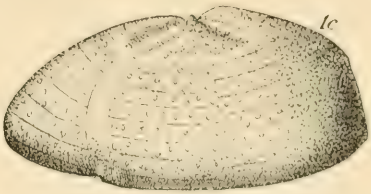
PLATE XLVII.

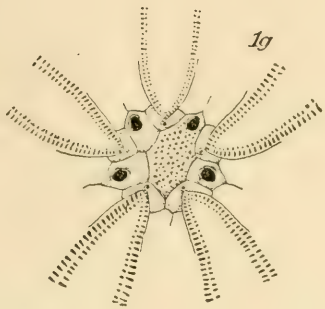
PLATE XLVII.

HEMIASTER TEXANUS Roemer (page 86).

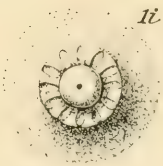
Fig. 1*a*. Upper surface of the test.
1*b*. Lower surface of the test.
1*c*. Lateral view of the same.
1*d*. Posterior view of the same.
1*e*. Several plates from the petaloidal region of the right postero-lateral ambulacrum, highly magnified.
1*f*. Ditto, anterior ambulacrum.
1*g*. Apical disk, much enlarged.
1*h*. Lateral view of a tubercle, highly magnified.
1*i*. Same from above.


1d

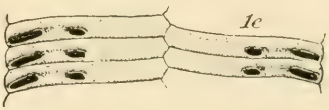

1c


1g

1f


1i

1h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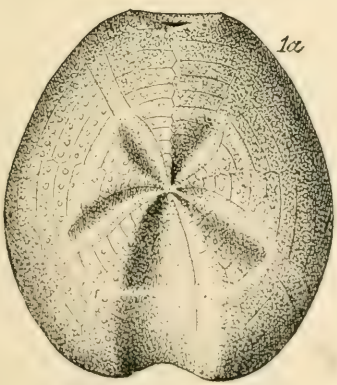
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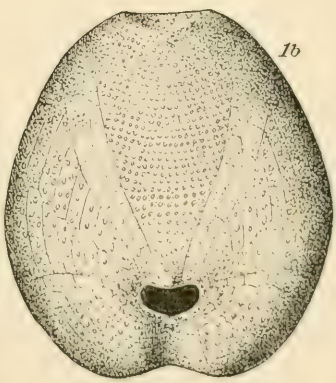

1b

HEMIASTER.

PLATE XLVIII.

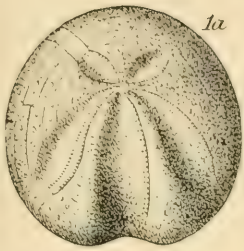
PLATE XLVIII.

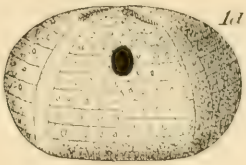
HEMIASTER HUMPHREYSANUS (Meek and Hayden) (page 88).

Fig. 1*a*. Upper surface of the test.
1*b*. Lower surface of the test.
1*c*. Lateral view of the same.
1*d*. Posterior view of the same.
1*e*. Several plates from the petaloidal region of the right posterior lateral ambulacrum, highly magnified.
1*f*. Ditto, anterior ambulacrum.

HEMIASTER DALLI Clark (page 89).

Fig. 2*a*. Upper surface of the test.
2*b*. Lower surface of the test.
2*c*. Lateral view of the same.
2*d*. Posterior view of the same.
2*e*. Several plates from the petaloidal portion of the left antero-lateral ambulacrum.


1a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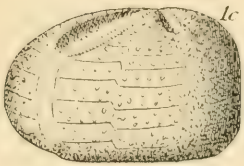
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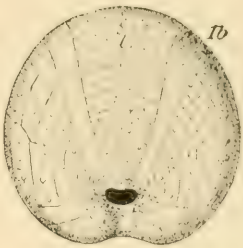
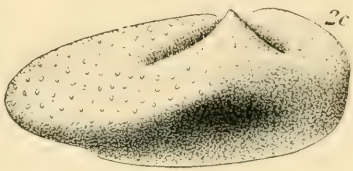

1b

1e

1f

2d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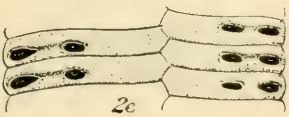
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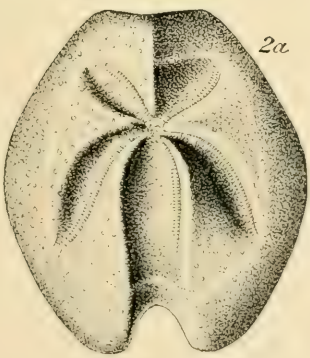
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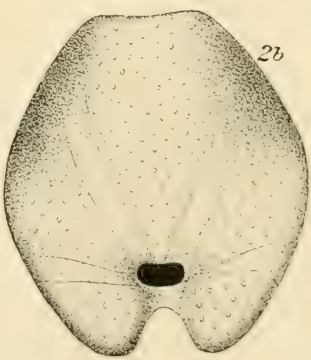

2b

HEMIASTER.

PLATE XLIX.

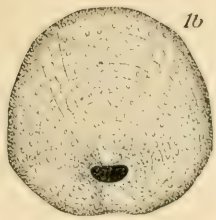
PLATE XLIX.

HEMIASTER CALIFORNICUS Clark (page 90).

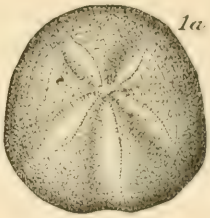
Fig. 1*a*. Upper surface of the test.
1*b*. Lower surface of the test.
1*c*. Lateral view of the same.

HEMIASTER CALVINI Clark (page 90).

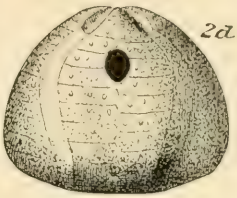
Fig. 2*a*. Upper surface of the test.
2*b*. Lower surface of the same.
2*c*. Lateral view of the same.
2*d*. Posterior view of the same.
2*e*. Several plates from the petaloidal region of the right postero-lateral ambulacrum, highly magnified.
2*f*. Same, lower portion of petaloidal region.
2*g*. Several plates from anterior ambulacrum.
2*h*. Interambulacral plate, enlarged.
2*i*. Apical disk, enlarged.


1b

1c


1a

2e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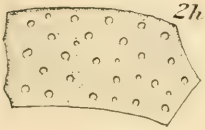
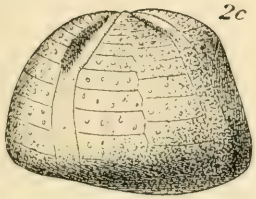

2h

2g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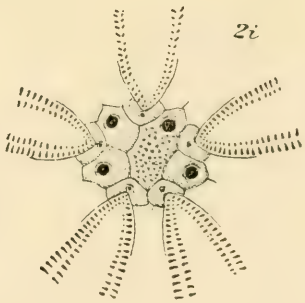
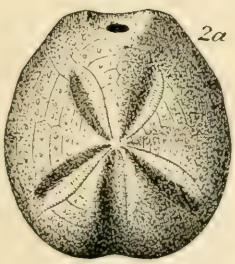

2i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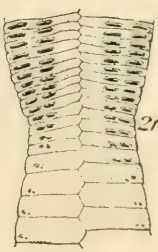
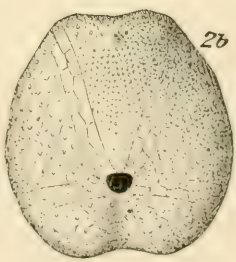

2f


2b

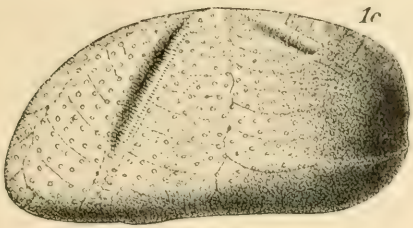
HEMIASTER.

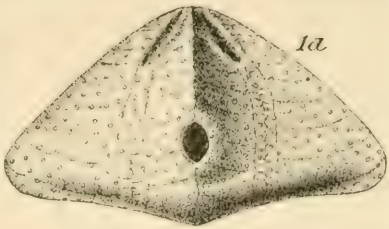
PLATE L.

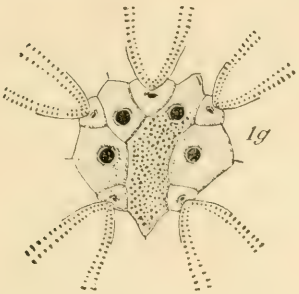
PLATE L.

LINTHIA TUMIDULA Clark (page 91).

Fig. 1*a*. Upper surface of the test.
1*b*. Lower surface of the same.
1*c*. Lateral view of the same.
1*d*. Posterior view of the same.
1*e*. Upper portion of the anterior ambulacrum, enlarged.
1*f*. Several plates from the petaloidal region of the left postero-lateral ambulacrum, highly magnified.
1*g*. Apical disk, enlarged.
1*h*. Tubercle from the side, highly magnified.
1*i*. Ditto, from above.


1c


1d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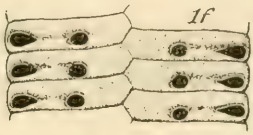
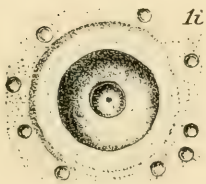
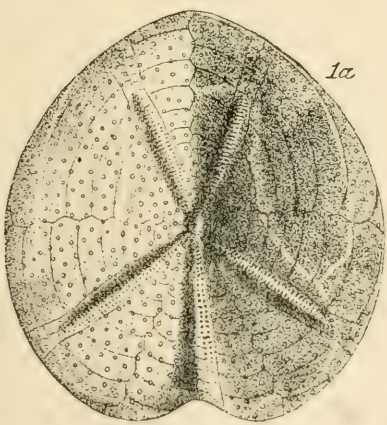

1f

1h


1i

1e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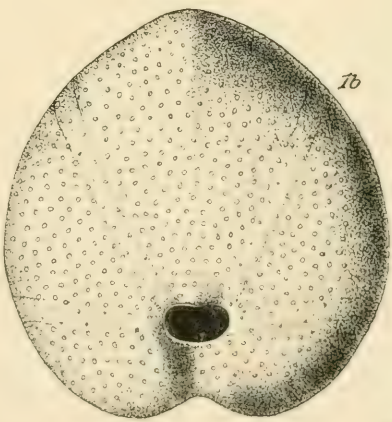
1b

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